
WIRED
UK EDITION
THE SECRETS OF
STAR WARS
JAN / FEB 16
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COLLECTOR'S
DOUBLE
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PLUS
FINALLY:
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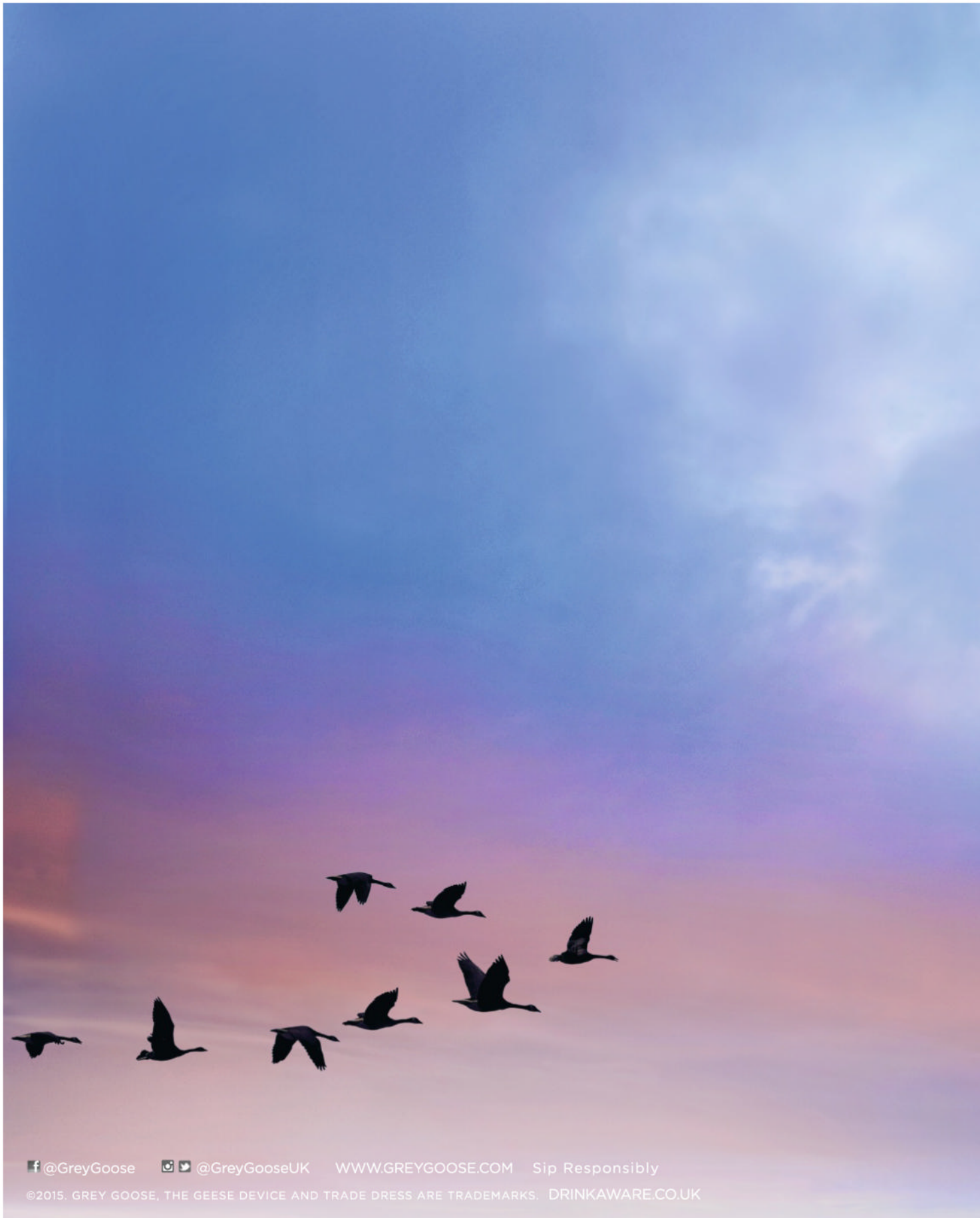
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The empire is back
Star Wars is back and bigger than ever. In this special feature, WIRED talks to director J.J. Abrams about *The Force Awakens*

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PHOTOGRAPHY: DAN WINTERS; JULES HEATH



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DEDICATED TO PERFECTION

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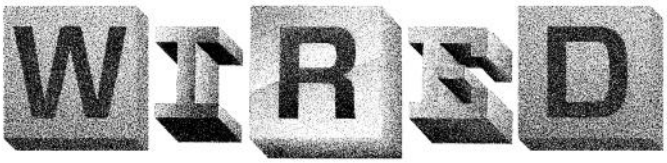
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PHOTOGRAPHY: NICK WILSON



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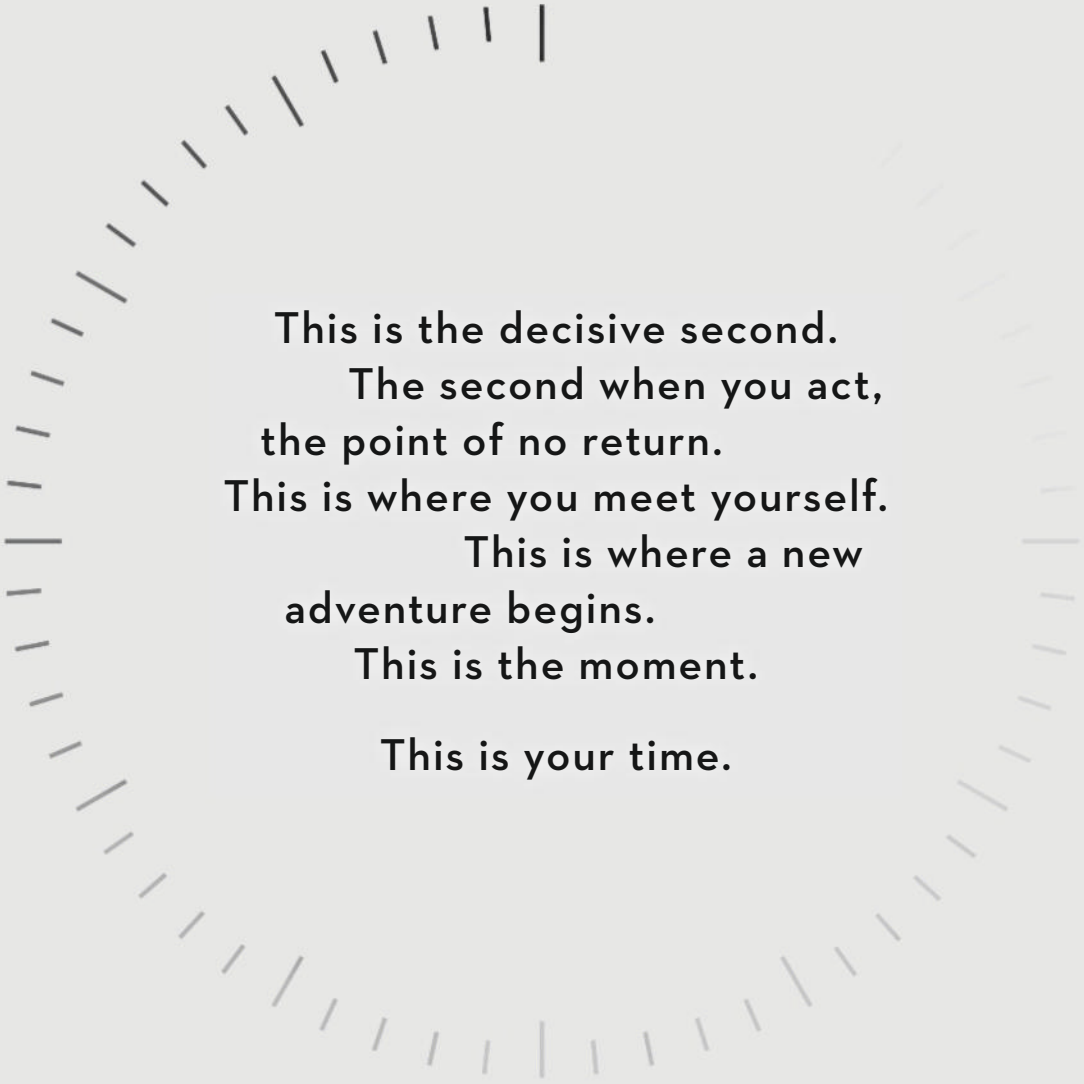
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This is where a new
adventure begins.
This is the moment.

This is your time.



ANDREW DIPROSE, YOU'RE OUR ONLY HOPE...

WIRED's creative director (*above, left*) gets to meet a true legend this issue: "What a privilege to go behind the very secret scenes at Pinewood. When R2-D2 arrived, I was a kid in 1977 again. I think I managed to play it cool for all of, oh, four minutes."



ROWLAND MANTHORPE

Manthorpe is WIRED's new associate editor, and he curates the Start section. "It's all big ideas," he says. "Start succeeds by looking further ahead than anything else. There are lots of stories that might be a good fit, but for me, they've got to have a touch of madness."



BACKSTAGE AT THE CONFERENCE

Creating the WIRED2015 group photo entailed two days of meticulous planning, but WIRED's Dalia Nassimi (*left*) and Steve Peck (*right*) got their shot, with help from Nick Wilson (*centre*). "It's great to meet so many inspirational people," says Wilson. "Pussy Riot's Nadezhda Tolokonnikova was a highlight, thanks to her impromptu, breathy rendition of 'Happy Birthday, Mr President.'"

CONTRIBUTORS



OLIVER FRANKLIN-WALLIS

WIRED's assistant editor gets this month's dream assignment: reporting on the new *Star Wars* film. "My career has now peaked, definitely," he says. "We avoided generating rumour-fodder and sought out the artists who make J.J. Abrams's galaxy so believable."



KATHLEEN RICHARDSON

Richardson, an expert in robotics and ethics, warns in Ideas Bank about the dangers of sex robots. "In a prostitute-client encounter, you are allowed to 'switch off' empathy," she says. "Do we want to encourage this by extending this lack of empathy to robots?"



KYLE WILKINSON

Yorkshire-based designer Wilkinson looked to a planet far, far away for this month's features opener image. "I wanted the reader to feel they were peeking at a new world so I studied images of Pluto," he says. "We decided to use hydrophobic sand, which you can sculpt underwater."



JAY BROOKS

Brooks rose to the challenge of photographing record-breaking sailor Hannah White. "We'd planned an action shot, but she'd fractured her arm," says Brooks. "So we decided to submerge her, while someone out of shot stopped the boat from blowing away."



RHODRI JEFFREYS-JONES

The author of *In Spies We Trust* reveals a big secret in Ideas Bank – that corporate surveillance is far more widespread and damaging than that by the state: "Just take the 'market research' behind cold call, the pop-up ad and the inexplicably declined mortgage."

It's time to believe in yourself.

TONY PARKER.

WILLIAM ANTHONY PARKER IS A FRENCH PROFESSIONAL BASKETBALL PLAYER IN THE NBA, ONE OF THE MOST TALENTED IN THE WORLD. HE HAS PROVEN THAT MEASURING 1.88 METERS IS NOT AN OBSTACLE FROM REACHING THE TOP.

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RE: HALF OF BRITISH JOBS AT RISK FROM ROBOTS, WIRED.CO.UK

"A two- to three-day working week, job sharing, higher wages… the big question is: what are we going to do with all our leisure time?" **Jake O'Neill, via Facebook**

"We could build the robots, until we've built a robot that builds robots, and when we invent the supercomputer/quantum computer we will become obsolete." **Marty Slackjaw, via Facebook**

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PIXELS VERSUS MEETING MUMMIES

"Great to see the British Museum's artifacts being digitised, but there is nothing like going in person (Tour the British Museum on Google Street View, wired.co.uk). Digitising museums makes them more accessible but I also worry it may make people less inclined to go and see the real thing. Last time I was there I came face to face with a mummified man from 3,000 BCE. The dry heat of the Egyptian desert had preserved the corpse so well he still had skin and tufts of red hair. It's important that we retain the physical objects from the human past, not just pixels of them." **Chloe Mack, view Facebook**

OFF-PAGE

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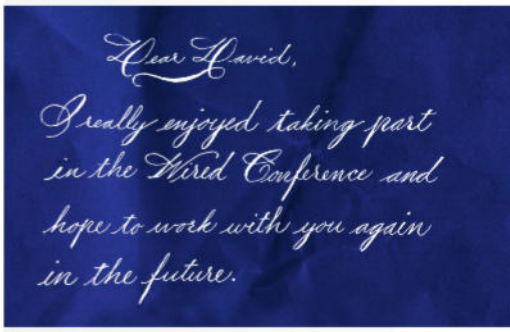
SOMETHING TO DIGEST

"'Obesity is not the result of eating too much and moving too little' (Fat is a neuro-cognitive issue, Ideas Bank 09.15) – except it is! To say otherwise would need a rewrite of the laws of physics. More energy in than is being used = weight gain, as our bodies are biochemically programmed to store excess energy consumed in our food as fat. This was a good move in our evolutionary history, but is a problem for those of us surrounded by highly calorific food. We need to convince ourselves that to beat growing levels of obesity we have to give up most of the highly processed food that we eat and make sure we consume the recommended amounts of fruit and veg. Right, now I've got that off my chest, I'm off for a pizza." **Ian Cowell, via Facebook**

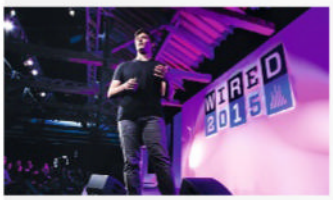
WIRED2015

FONT MASTER

Comic Sans maker Vincent Connaré, a WIRED2015 speaker, sent us this lovely note. However, the post office had trouble with our address, written in the same font. What's wrong with Comic Sans?



Want to air your views on WIRED? Get in touch: rants@wired.co.uk



WIRED2015

BRING ON THE FUTURE FOOD

"I am on board with Hampton Creek's Josh Tetrick (*above, at* WIRED*2015*). Bring on the egg-free mayonnaise and other products, and my wife and I will consume them. I am finished with animal products. After having been on this route for six years at 61 years of age, there is no turning back. We love it !" **Jerry Howe, via Facebook**

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Ramon Mayor, driver for on-demand chilled-food delivery service EatFirst

PHOTOGRAPHY: DAN BURN-FORTI

FROM THE EDITOR

There are a few cultural touchpoints that will be forever WIRED. Whether it's a Bjarke Ingels skyscraper, a new Pixar movie or a LEGO product launch (at least, before they started messing with our friend Ai Weiwei), you can guarantee an opinionated buzz sweeping through our Hanover Square office. So you'll understand why the combination of J.J. Abrams and the revived *Star Wars* franchise pressed all our intergalactic buttons. Star Destroyers, lightsabers and spin-off comic books? The force is well and truly with us this issue.

WIRED assistant editor Oliver Franklin-Wallis put together this issue's cover story, writing a revealing interview with Abrams and diving deep into the wider *Star Wars* subculture. As editor of our Play pages, Franklin-Wallis has the job I secretly crave – only last month he hung out with Pixar's John Lasseter, Danny Boyle and Linkin Park for us. You'll enjoy his interview even if you don't consider yourself a hardcore *Star Wars* fan. Because, amid any new blockbuster's hype, it always helps to understand the context.

We wanted to learn a bit more about the on-demand economy this month. So we followed a few of its workers to understand the realities of their day – and whether they felt they were being liberated or exploited. You'll draw your own conclusions, but as the sector grows we're going to be hearing a great deal more about what rights the workers do or don't have in an ever more monopolistic sector of the economy.

You may notice that this issue is thicker than usual. That's because it's a double issue, at the regular cover price, as we adjust our publication schedule to align with our community's changing media habits. Along with the other international WIRED editions, we're altering the regularity of print and app publication to devote more focus to our daily journalism on platforms ranging from the wired.co.uk website to Apple News. We're boosting our investment in quality storytelling in all the ways that reach you today – with our weekly podcast, our daily free email WIRED Awake morning bulletin and *The* WIRED *World in 2016*, not forgetting seven ambitious live events planned for 2016. We're also about to boost our team's output of regular video stories.

As a consequence, we'll be combining our January and February editions, as well as our July and August editions, as double issues. We love the printed artefact that is the monthly magazine, and are no less committed to this format than when we launched seven years ago. But the world is now engaging with ideas through smartwatches, tablets and virtual-reality lenses that weren't around when we began. And so, as the magazine of the future, WIRED will be where you are. Including when you feel like shiny printed pages.



David Rowan

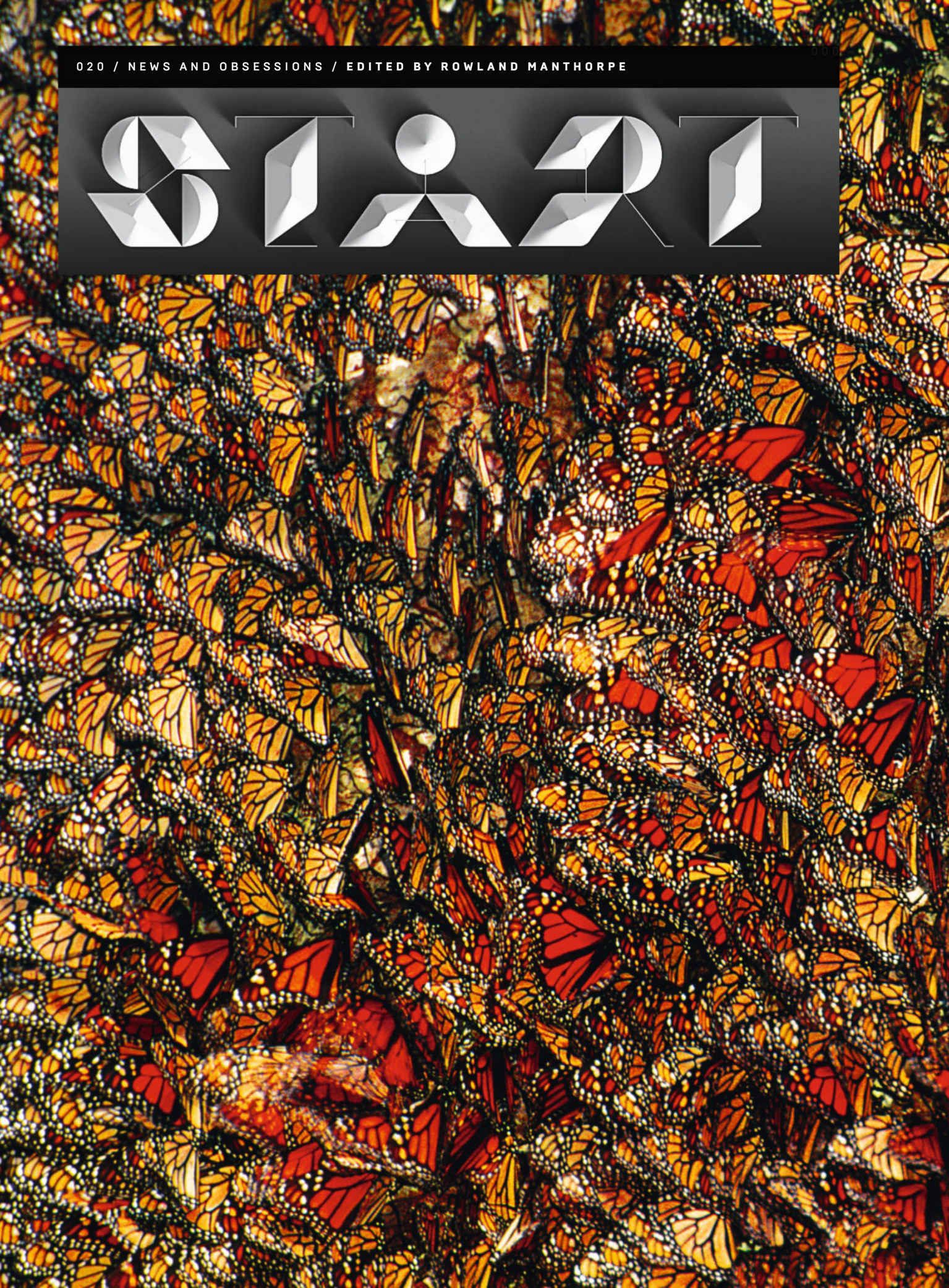
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FLYING DOWN THE FREEWAY

Every autumn, millions of monarch butterflies fly up to 3,200km from North America to gather in a tiny patch of forest in Michoacán, Mexico (*pictured*). But their numbers are falling fast. "As recently as 1993, more than a billion butterflies would overwinter in Mexico," says Daniel Ashe, director of the US Fish and Wildlife Services. "In 2013, there were just 33 million. That's a 97 per cent drop." The reason: increasingly efficient agricultural practices eradicating the milkweed that is the monarch caterpillar's sole food source.

To combat this, in May 2015, the White House announced the creation of a 2,400km monarch migration highway that will follow the route of Interstate 35 from Minnesota to the bottom of Texas. "We're going to enlist transportation departments, utility companies, farms, school groups and homeowners to plant milkweed along the route," says Ashe. "Whether it's in back yards or a national park." The goal is to restore the overwintering population to 225 million by 2020 – and inspire future environmentalists. "They will learn that their little bit can add up," Ashe explains. "When it comes to dealing with something like climate change, they will remember this." **Kathryn Nave**

RAYMOND WEIL
GENEVE



IN PARTNERSHIP WITH Piper

Mr. Raymond Weil's other great passion was undoubtedly aviation. He was a true pilot and particularly loved to fly his Piper aircraft around the Matterhorn. In his honour, a unique freelancer Pilot special edition watch was created in partnership with legendary general aviation manufacturer Piper Aircraft Inc.

Join the discussion **#RWPiperAircraft**

Special Edition - ***freelancer***

RESCUE ROBOTS THAT DATA-DIVE

Robin Murphy's autonomous workmates save lives in record time

ROBIN MURPHY PROVIDES A SPECIAL KIND OF EMERGENCY HELP: ROBOTS. IN THE WAKE of 9/11, the director of the Texas-based Center for Robot-Assisted Search and Rescue sent squirrel-sized rescue bots into the rubble of the World Trade Center. In 2011, she used sonar-equipped remotely operated underwater vehicles to evaluate ports and piers after the Japan tsunami. "They can do things that people can't do," says Murphy. "And they can act in situations where humans would be extremely limited."

Because they don't have to worry about safety, robots can achieve a great deal in a short amount of time. When the Oso, Washington, mudslides occurred in 2014, Murphy and her flock of UAVs took seven hours to gather necessary information about the hydrology and geology of the landscape. Without robots, it would have taken two to four days to compile the same intelligence, at a much lower resolution. "UAVs were able to get accurate data from angles that you couldn't get from a satellite," she explains. The only downside is the sheer amount of information that can be gathered. "It's called a data avalanche," says Murphy. "You get more data than you can actually go through."

The next step is using AI to do the work for them instead. During the mudslides, deep-learning programs were used to train computers to go through photographs and identify details that a human would miss, such as pieces of debris big enough for a person to be trapped under. "Having computers able to detect something we didn't and to specify it within 20 minutes, not two years – that's really exciting," says Murphy. **Sophia Epstein** *crasar.org*

Robin Murphy at Disaster City training centre in College Station near Houston, Texas

1. AOES Marcy Marsupial unmanned surface marine vehicle

2. Inuktun American Standard Robotics Micro-VGTV Extreme (*top*); QinetiQ Dragon Runner

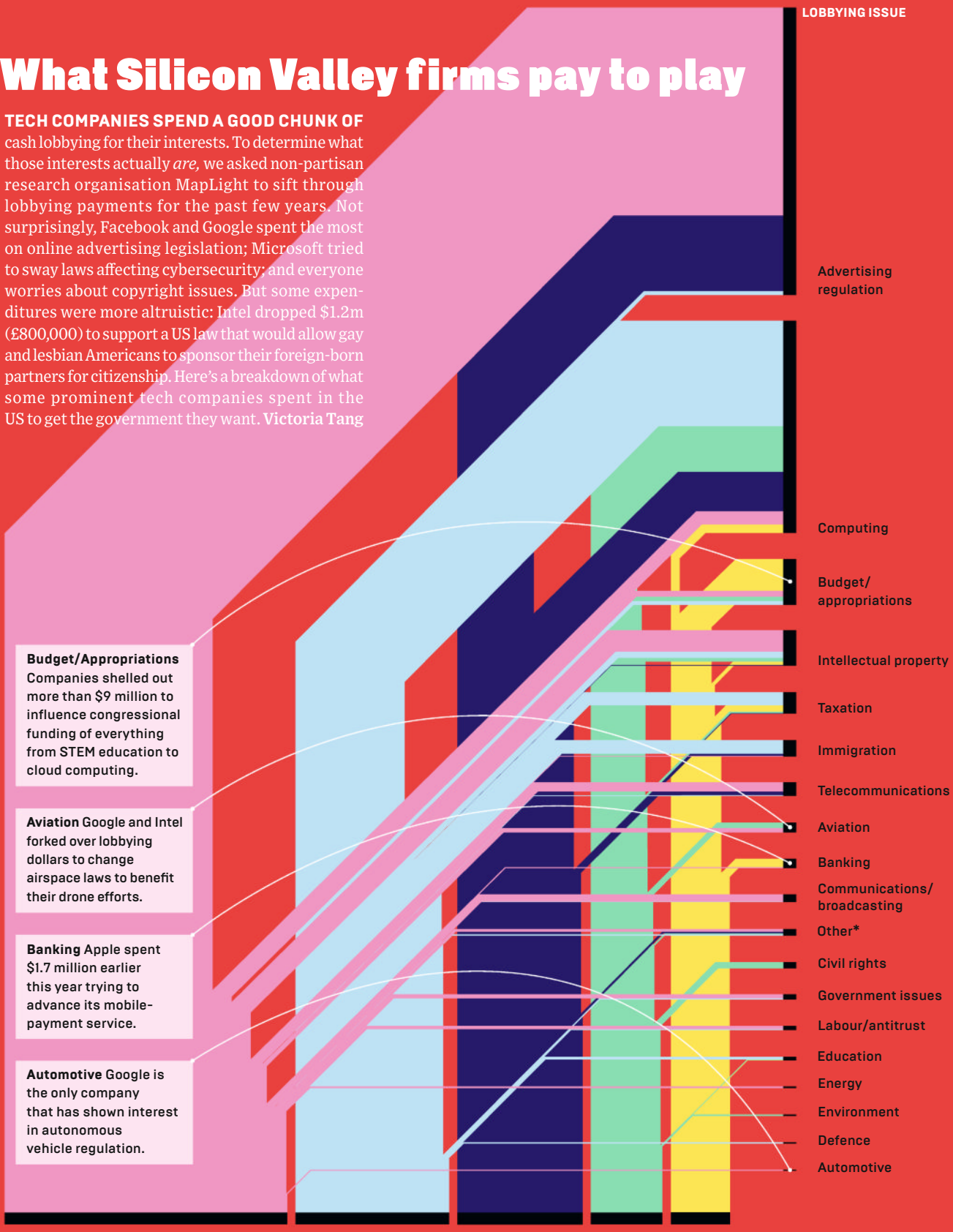


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What Silicon Valley firms pay to play

TECH COMPANIES SPEND A GOOD CHUNK OF cash lobbying for their interests. To determine what those interests actually *are,* we asked non-partisan research organisation MapLight to sift through lobbying payments for the past few years. Not surprisingly, Facebook and Google spent the most on online advertising legislation; Microsoft tried to sway laws affecting cybersecurity; and everyone worries about copyright issues. But some expenditures were more altruistic: Intel dropped $1.2m (£800,000) to support a US law that would allow gay and lesbian Americans to sponsor their foreign-born partners for citizenship. Here's a breakdown of what some prominent tech companies spent in the US to get the government they want. **Victoria Tang**



SOURCES: MAPLIGHT; OFFICE OF THE CLERK OF THE U.S. HOUSE OF REPRESENTATIVES; SENATE OFFICE OF PUBLIC RECORDS

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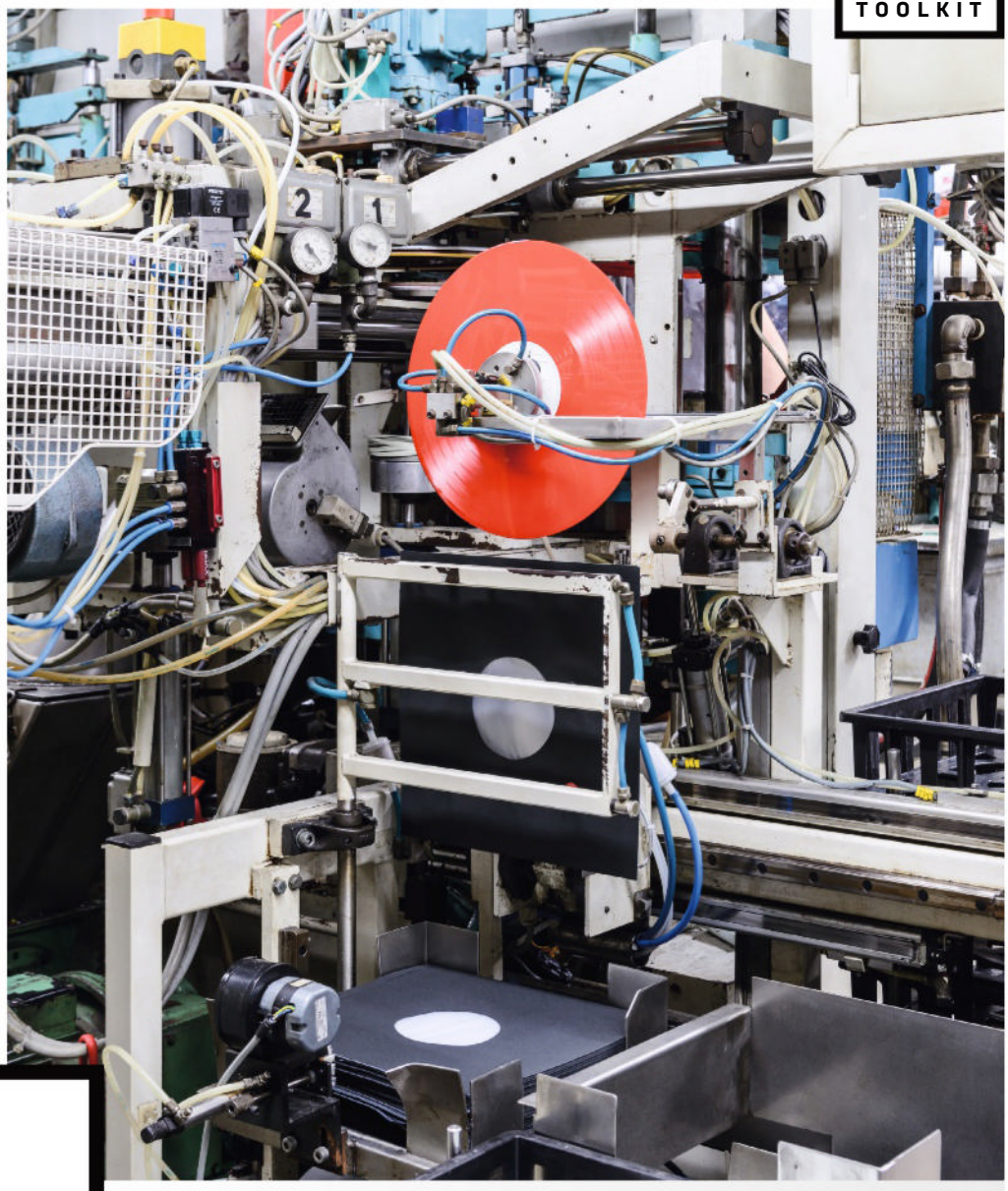
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PACKAGER
Once the excess vinyl has been cut away, the disc (here, a red one – Record Industry specialises in colours) can be fed into its inner sleeve. After that, it is transported to a warehouse to cool off, before being packed in to an outer sleeve. It is then ready to be sent to the record company and on to the distributor and retailers.

WANE AND WAX

Our series on tools for trades comes to a Dutch factory at the forefront of the vinyl revival

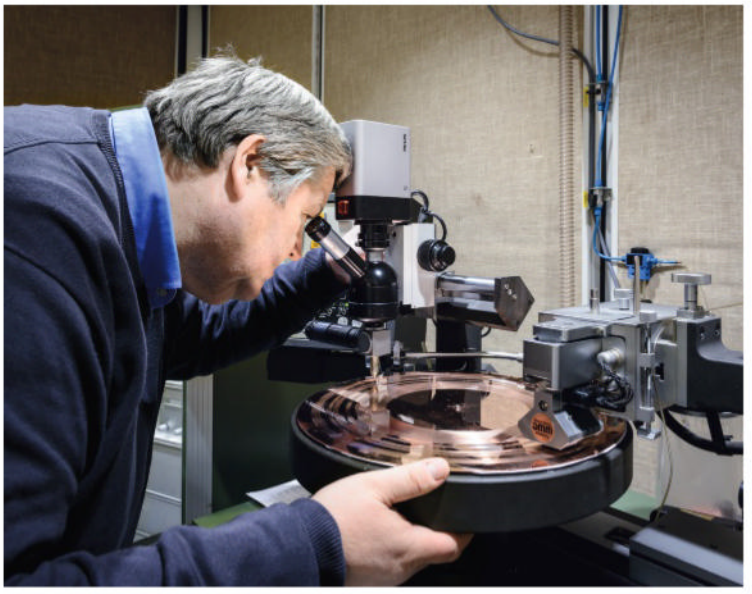
REMEMBER VINYL? IT'S NOT DEAD: in fact, the biggest pressing plant in Europe is working at full capacity. Here in Record Industry, a 6,500m² factory in the northern Dutch town of Haarlem, 7.5 million vinyl records will be produced this year for artists including Ed Sheeran and Miles Davis – up from 3.8 million in 2013. "The entire world music industry is after vinyl," says Anouk Rijnders, sales manager at Record Industry. "We had to double our shifts to meet demand – and it's still not enough."

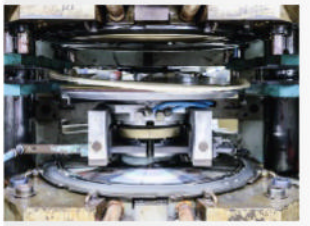
Record Industry creates each record from nothing, cutting copper and lacquer masters, pressing vinyl pellets, even printing the sleeves. It's a complicated, expensive process (each record costs just over £2 to make), but with record labels going through their back catalogues to re-release albums on vinyl, Rijnders expects this growth to continue. In the last year, the company has expanded from 50 to 110 employees, and could press as many as "eight, nine or ten million records" in 2016. The reason for this revival? "There's no emotion to having music on MP3," says Rijnders. "Music, for some people, is still something they'd like to own." Get into the groove. **RM** *recordindustry.com* >

PHOTOGRAPHY: ALASTAIR PHILIP WIPER



GALVANIC BATHS
These are used to make copies of the master. A thin layer of nickel sticks to the grooves of the master through a process known as electroforming. When this is peeled away, it forms a precise negative of the original disc.





CUTTING ROOM
Here, digital audio is mastered for vinyl and transferred to analogue. Rinus Hooning, Record Industry's head of audio and quality control, watches the vibrations of a diamond stylus cut a groove on a copper disc.

STEAM BOILER
PVC is heated in an extruder and then shaped into a puck, which is pressed by squeezing it at a pressure of 150 bar against the nickel negatives (known as "stampers"). Records typically come in black, but this disc will be gold coloured.

PHOTOGRAPHY: ALASTAIR PHILIP WIPER



drinkaware.co.uk for the facts

PLEASURE IN A SINGLE MOMENT

Our Spey Cascade Single Malt Scotch Whisky. Slowly distilled then matured in a perfect balance of American & European oak casks, to evoke subtle hints of autumnal fruits. For a smooth and rich taste you'll enjoy from the first sip.

THE SINGLETON.

THE SINGLETON and SPEY CASCADE words, the Fish & Gate device and associated logos are Trade Marks. © Diageo 2015

Haptic controllers: look but don't touch

Ultrahaptics' palpable sonic sensations could bring about new ways to control a car or play computer games



TOM CARTER CREATES sounds you can touch. As the co-founder of Bristol-based Ultrahaptics, Carter has developed a technology that uses arrays of speakers, similar to a car's parking sensors, to produce ultrasounds that create tactile sensations. These sonic objects can be "touched" from up to two metres away.

Carter (*pictured*) came up with the idea in 2011 while studying computer science at the University of Bristol. "The idea of touching something that's not there had never been done in a way that was small and fast enough to give a good experience," he says.

The company's goal is not to create products, but rather to provide its technology to other industries. Carter underlines, for instance, how Ultrahaptics could add tactile kicks to virtual-reality gaming. He also says haptics might make possible appliances operated with ultrasound-sculpted buttons or switches. "Imagine a toaster you can control by making a gesture near it, and getting a lever-like sensation on your fingertips," he says. "According to what the tracker sees, we can update what the ultrasound makes you feel."

Jaguar is one company quick to spot its potential. In September 2015, it struck a partnership with Ultrahaptics to design a touchless dashboard for car drivers to control. Companies in other sectors – from consumer electronics to computing and gaming – have also been in touch. "People want to be the first in their field to have the technology," says Carter.

The idea might sound far-fetched, but if you ask Carter, it's going to arrive sooner than you'd expect. "We are trying to get a product to market in a short time," he says. "Hopefully, within two years, there'll be something that you can buy and control without touching."

GV *ultrahaptics.com*

PHOTOGRAPHY: ANDY GLASS



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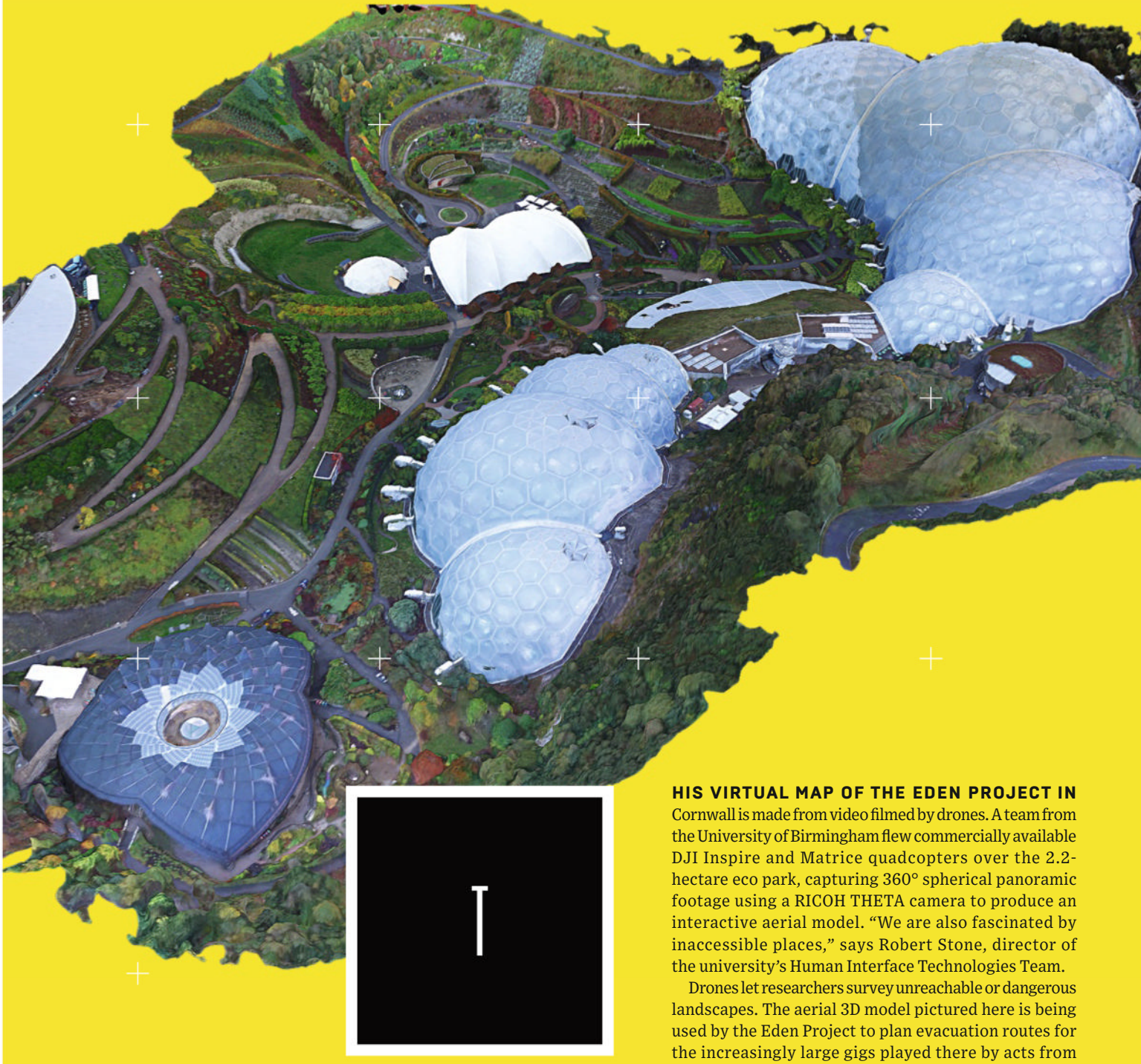


MANAGE + SHARE
GOPRO APP + GOPRO STUDIO

#BEAHERO

3D VIEWING WITH ALTITUDE

Need to map shipwrecks, war zones or evacuation routes for tourist destinations? Send in the drones



Digital extra!
Download the WIRED app to explore the 3D-mapped Eden Project

THIS VIRTUAL MAP OF THE EDEN PROJECT IN Cornwall is made from video filmed by drones. A team from the University of Birmingham flew commercially available DJI Inspire and Matrice quadcopters over the 2.2-hectare eco park, capturing 360° spherical panoramic footage using a RICOH THETA camera to produce an interactive aerial model. "We are also fascinated by inaccessible places," says Robert Stone, director of the university's Human Interface Technologies Team.

Drones let researchers survey unreachable or dangerous landscapes. The aerial 3D model pictured here is being used by the Eden Project to plan evacuation routes for the increasingly large gigs played there by acts from Elton John to Motörhead. The team is also helping Goonhilly Satellite Earth Station evaluate sight lines for geostationary satellites, and guiding archaeologists around shipwrecks. "Some of the sites we're investigating are so dangerous that we couldn't rescue one of our drones if it went down," says Stone.

The drones can be programmed to fly over the sites. Once filming has been completed, the video is converted into 3D using the Unity 3D development platform. "A single-battery flight and a few hours of processing saves weeks of work building a model manually," says Stone. The team is also working with the Ministry of Defence to explore "sacrificial" drones, which Stone says could gather key intelligence before being shot down or losing power. That's our kind of killer drone. **Mark Piesing** *birmingham.ac.uk*

Why wait for your gap year to travel the world?

Joann McPike's school classroom extends from Costa Rica to Japan

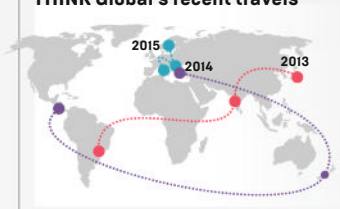
Most schools organise field trips – at THINK Global, the school *is* the trip. Since 2010, the travelling boarding school has been spending each three-month term in a different country, moving its 20 staff and 45 teenage students from Athens to Costa Rica in the space of a year. "I think to understand the world you have to see it," says THINK Global founder Joann McPike. "There's an empathy there that you don't get if you just stay at home."

McPike, 49, an award-winning travel photographer before THINK Global, came up with the idea when she was looking for schools for her son Alexander. "We didn't want him to be dropped into a high school that would teach him one way of thinking," she says. "So we decided to start a school." THINK Global hires hosts and partners with local schools, tailoring its International Baccalaureate curriculum to each country's conditions. Studying Homer in Greece, for example, pupils took a boat trip to the locations mentioned in *The Odyssey*.

THINK Global, which will travel to Sweden, Bosnia and Italy over the next school year, costs $79,000 (£50,000) a year to attend. McPike, who funds the non-profit from a foundation which covers 86 per cent of running costs, emphasises that "it's not a school for rich kids – but for the right kids." (She also sponsored tickets at WIRED: Next Generation). Entry, at tenth grade (or UK year 11), is selective and tuition fees can be adjusted to suit families' finances. "We do what we feel is fair," says McPike, who wants to bring the THINK Global model to a wider audience.

All this travel, of course, brings the odd mishap. Studying in the Serengeti, students and staff had to be evacuated from a mud pit; and after getting caught up in the Boston Marathon bombing, teachers were forced to run classes in the students' residence. But with departing alumni accepted at universities around the world, and Alexander, now 19, at Harvard, the adventure is paying dividends. "Someone asked me how I measure success," says McPike. "We want them to leave thinking no idea is too big." **RM** *thinkglobalschool.org*

THINK Global's recent travels





THINK Global students travelled to the Misiones province in Argentina to study water cycles and biodiversity



CREATOR OF A COOLER ENGINE

Michael Dearman hauled an invention out of deep-freeze to fix refrigeration

MICHAEL DEARMAN IS preparing for the realisation of a family dream. Almost 40 years ago, his father, British inventor Peter Dearman, came up with the idea of an engine powered by liquid nitrogen. Next spring, the prototype will finally be tested on public roads – not in a car, as Dearman intended, but as a replacement for the auxiliary engines bolted on to the side of refrigerated trucks. "I have seen the engine grow from an idea in my father's head to a piece of machinery," says 34-year-old Dearman (*pictured*), head of development at the company named after his father, now 64.

Liquid nitrogen engines have been a goal since nitrogen was first liquefied in the 1880s, but progress was slowed by the challenges of building engines to use fuel at -196°C – nitrogen's boiling point. Dearman says his company now found a niche for its technology by using his father's engine to deliver cold and power at the same time.

The engine produces power like a petrol engine, with liquid nitrogen expanding to drive a single piston. Before the nitrogen gets to the engine, however, it has absorbed the heat of the refrigerated compartment through a heat exchanger. This latent heat changes the nitrogen into a gas without any increase in temperature. It is then injected into the cylinder to mix with a water-glycol fluid, which enables the gas to expand at a consistent and efficient rate, a feat previous attempts at liquid nitrogen engines have struggled with.

The company has teamed up with transport refrigeration suppliers Hubbard Products Ltd to develop the engine in preparation for a larger trial – potentially with a supermarket – in the spring. But does it matter that Dearman's vision is powering fridges, not cars? "My dad did run a car using a Dearman engine," says Michael. "Just because it works in principal doesn't mean it's the best use for a technology." **Mark Piesing** *dearman.co.uk*

APPS OF THE MONTH

◂ WIRED

LUMINO CITY

Hunt for Lumi's missing granddad and discover his secrets in the nooks of this absorbing game, which took three years to make by hand and has already won the team a Bafta. *iOS, Apple TV, Windows, £3.99 luminocity game.com*

THIS.

This. is a link-sharing app that unobtrusively showcases the most popular online stories. Users can only share one link per day, so the posts tend to be well curated. Great inspiration for the commute. *iOS, free this.cm*

PAUSE

PAUSE is a meditation app designed to create moments of calm in busy lives. Follow a growing blob across your device's screen with your finger until it fills the screen, close your eyes and relax. *iOS, Android £1.49 ustwo.com*

BOOMERANG

Instagram's younger brother takes bursts of ten photos and knits them into a one-second video that repeatedly plays the sequence forwards then backwards – for that boomerang effect. *Android, iOS, free instagram.com*

CLEANSPACE

This clever app lets you earn real-world rewards when you opt for a "clean" travelling option such as walking or cycling. You can also invest in a *CleanSpace* Tag air monitor to help you avoid polluted routes. *iOS, Android, free our.clean.space*

◂ WEIRD

KIBO

Use *Kibo* with your messaging app to mask secret messages with asinine ones. If you and a friend both have the app you can encrypt and decrypt your chats to deter spying eyes. *iOS, free kiboapp.com*

Cara McGoogan

PHOTOGRAPHY: JOE MCGORTY

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DISRUPTING THE DNA TEST

Whether you're testing a restaurant's sushi or a child's paternity, the Bento Lab makes it easy

This little kit contains everything needed to uncover the next horsemeat scandal. "It's got all the key tools of molecular biology," says Bethan Wolfenden, co-founder of Bento Lab. "You can go from a DNA sample – whether that's saliva or food – all the way through to identifying a particular gene and comparing it to another sample."

"Lab kit has to be very accurate – that's why it's so expensive," says co-founder Philipp Boeing. "But for education, prototyping or field work it might be OK to trade this off and have 99 per cent accuracy, rather than 99.9, if the kit is a tenth of the price."

Fifteen of the 3kg, 30cm x 21cm x 5cm Bento Labs have been sent to researchers, educators, biohackers and artists for beta-testing, at a cost of £450 per kit. A professional polymerase chain reaction (PCR) machine (*see below*) costs about £20,000. "People have tested sushi to see if restaurants really are serving tuna," says Wolfenden.

The plan is to distribute Bento Lab through schools and universities. "They are much easier to work with in the sense of supply chains," says Boeing. "But we're also thinking what a 16-year-old whiz-kid might do with one at home." **KN** *bento.bio*

1. CENTRIFUGE
This spins a sample around to separate the different parts of a cell by weight, allowing the kit to extract the DNA.

2. PCR MACHINE
The PCR creates millions of copies of a specific section of DNA, such as a gene, allowing you to select the part that you are interested in.



3. GEL ELECTRO-PHORESIS
This uses an electrical current to separate out DNA by length, allowing you to check which gene you've selected.

PHOTOGRAPHY: STEPHEN LENTHALL

WHERE CARS LEARN TO DRIVE

A custom-made town in Michigan enables novice driverless vehicles to develop their road skills



DRIVERLESS CARS ARE PROWLING THE streets of Mcity – an ultra-realistic test site in Ann Arbor, Michigan. "A complex urban environment is always the most challenging for automated vehicles," says Peter Sweatman, director of the University of Michigan's Mobility Transformation Center, which led Mcity's development. "We wanted to create the ultimate testing environment for that situation." Since Mcity opened in July, six of the centre's 15 partners – a list that includes global car manufacturers such as Ford, Nissan, Honda and Toyota – have tested at the facility.

The 13-hectare fake town simulates the road features you'd expect to find both in a city centre and further out into the countryside – from roundabouts and pedestrian crossings to intersections and a stretch of motorway. And it's fitted with a network of sensors, so every car – and robot pedestrian – can be monitored at all times.

"On one of our suburban residential-style streets, we have a simulated tree canopy," says Sweatman, explaining that the moisture content of trees can block GPS signals. "We've created a netting structure where we can produce a



An aerial view shows the centre's two-, three- and four-lane road layout



variable moisture content through a system of capillaries. That's a completely unique test." Other challenges include a signal-blocking tunnel, a railway crossing and a metal bridge constructed in such a way that it interferes with radar systems' capabilities in identifying it as a horizontal surface.

The mission of the centre is not only about improving the technology that goes inside the cars. "We hope that the scenarios we create in Mcity will form the basis for the regulatory standards that are going to apply to driverless vehicles," says Sweatman. Once these standards are set, and the self-driving technology is perfected, Mcity-tested cars will hit streets in the real world. "Our ultimate goal is to set up a service with a couple of thousand vehicles for people in Ann Arbor to use as a new kind of on-demand mobility service," he says. Watch out, Uber. **Sophia Epstein** *mtc.umich.edu*

EARLY ADOPTERS



WHAT'S EXCITING...

ALI MERUANI

Founder,
eet

"**Netatmo's environmental sensors** can measure everything from humidity, air pressure and CO_2 levels, to noise and temperature. It is amazing to see how indoor spaces change over the course of the day, together with our perception of those spaces."



WHAT'S EXCITING...

JOANNE SMITH

CEO,
RecordSure

"I love entertaining at home, and I was thrilled when I came across the Kickstarter for the **icebreaker**. It's an ice-cube maker that allows you to add flavours to ice cubes – just top it up and put it in the freezer. It also looks great: you rotate the top and nice chunks of ice pop out."



WHAT'S EXCITING...

DAVID WOOD

Chair,
London Futurists

"Robert Wachter's ***The Digital Doctor*** is an intelligent analysis of how computerisation of health records has, so far, failed to deliver expected improvements. It's a reminder for technologists to keep usability design in mind."
Kathryn Nave

Introducing MotoShatterShield™ Technology.

The world's first shatterproof screen.



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Powered by:
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The new Moto X Force combines 5 rigid screen layers to absorb any impact. The latest Qualcomm Snapdragon™ processor lets you play, stream and multitask as fast as you want. Our 5MP and 21MP cameras with flash on both sides let you capture any moment in stunning detail, whether it's a selfie or a landscape. And with up to 48hrs battery life and TurboPower™ giving you 13hrs charge in just 15 minutes, it's truly made to keep you moving. Visit Motorola.co.uk for more.

The display and embedded lens are warranted against shattering and cracking for four (4) years from the original date of purchase; scratches or other damage to the protective lens is not covered by this warranty, but should always be in place to prevent scratches and other damage to the underlying components. This phone is not shockproof or designed to withstand all damage from dropping. All other warranty exclusions, including scratches and other cosmetic damage, intentional damage or abuse, normal wear and tear and other limitations apply. © 2015 Motorola Mobility LLC. All Rights Reserved. MOTOROLA and the Stylized M Logo are registered trademarks of Motorola Trademark Holdings, LLC. Android, Google and other marks are trademarks of Google Inc.



Syed Karim: "The Outernet is a universal information system"

WEB WORLDWIDE

Outernet are using satellites to provide free online content to the developing world

ABOUT 4.4 BILLION PEOPLE around the world don't have internet access. Syed Karim (*above*) and his New York based non-profit Outernet want to change that – by broadcasting free web content, worldwide, using satellites and radio waves. "We liken it to a public library in space," says Syed, 38.

Connecting to the internet via satellite is prohibitively expensive, so Outernet uses datacasting – think radio, but with web pages. Outernet's satellites broadcast data; as they pass overhead, a $99 (£65) receiver downloads and converts the data into cached web pages, audio or video. "It's not that different from short-wave radio," Syed says. Outernet's curated broadcasts include Wikipedia pages, ebooks and maps, along with regularly updated content such as news – once it has been downloaded, this material can be shared locally over Wi-Fi. Users use SMS to request new content for the satellites' next pass. "We're seeing strong demand for healthcare information in remote areas and educational materials," says Syed.

An American born to parents from Bangladesh, Karim was inspired by his father, who grew up in rural India. "He would get one book a year. But he wanted any access to information he could find, so he built a short-wave radio," he says. Founded in 2014, with funding from the Media Development Investment Fund, Outernet has run successful trials in sub-Saharan Africa and already broadcasts 1GB daily worldwide from seven satellites. It will soon begin launching its own nanosatellites to improve coverage. "We plan to be delivering 10GB daily everywhere in the world by the end of next year," says Syed. In January 2015, it raised $673,203 on Indiegogo to create Lantern, a compact solar-powered receiver that doesn't require a dish.

The receiver requires no additional software and is compatible with all browser types



Although Outernet may never provide true internet access, Karim believes that even simple information will be transformative for disconnected communities. "There's a school in Kenya we've put a dish in. They had a computer, but they had to walk two hours to find a Wi-Fi connection," he says. "With Outernet they can do it in their village."

Oliver Franklin-Wallis *outernet.is*

PHOTOGRAPHY: JORDAN HOLLENDER

BUILDING GREENER CITIES

Fungi bricks, solar-panel windows and giant 3D printers are creating more eco-friendly housing

IN 20 YEARS' TIME YOU COULD BE LIVING IN A SKYSCRAPER made of wood, with solar-panel windows, along a road that repairs itself. Yet so far such experimental methods and materials have been confined to one-off buildings. "There's no shortage of ideas, but the construction industry is slow," says Pete Walker, director of the University of Bath's BRE Centre for Innovative Construction Materials. "Getting ideas from the drawing board into buildings can be a long and expensive process."

For mushroom- or CO_2-made bricks to break into large commercial builds it's going to take more than publicity. "The industry tends to respond better to sticks than carrots," Walker says. "Traditional inorganic materials like cement, bricks and metal rely on low-cost energy, so as costs go up we've seen an interest in more cost-competitive bio-based or waste-based building materials such as hemp, flax and reeds. As energy costs continue to rise, so the way we build will change." Here's how WIRED would construct the city of the future. **Kathryn Nave**

1. CO_2 BRICKS
A pilot plant, set up at Australian mining-explosives company Orica's facility, will extract carbon dioxide from the air and turn it into a solid, inert carbonate for use in materials.

2. HEMPCRETE
Created by mixing the stalk of the hemp plant with a lime-based binder, hempcrete is lightweight, fireproof, waterproof and significantly more eco-friendly than concrete.

3. STRESS-DETECTING GEL
Created at the Massachusetts Institute of Technology, this gel changes colour in response to mechanical stress and warns of structural issues.



WIRED	TIRED	EXPIRED
DarthJarJar	General R2	**HanShotSecond**
Bingeing TV tropes	**Netflix & chill**	Box-set marathons
Vargr	Spectre	**SMERSH**
Footgolf	**Golf**	Football
Twitch installs	Twitch Bob Ross	**Twitch *Pokémon***

ILLUSTRATION: TERENCE EDUARTE

4. MUSHROOM BRICKS
Created as an eco-friendly substitute to polystyrene, Ecovative's moulded mycelium fungi have also been used in biodegradable bricks for temporary constructions.

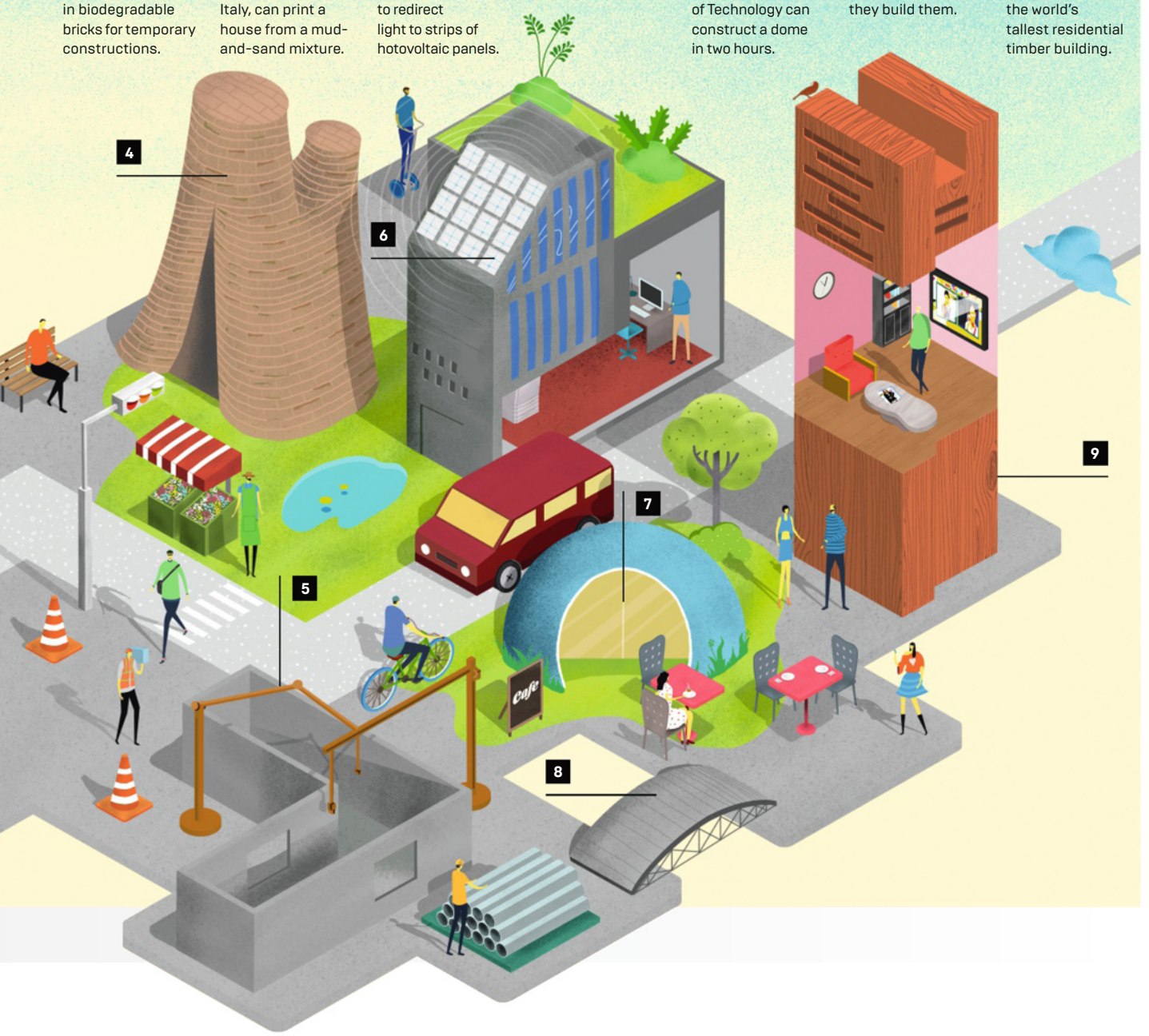
5. 3D-PRINTED BUILDINGS
At over 12 metres tall, the world's largest 3D printer, built by World's Advanced Saving Project, based in Italy, can print a house from a mud-and-sand mixture.

6. SOLAR-PANEL WINDOWS
Developed by Silicon Valley's Ubiquitous Energy, the first fully transparent solar panel uses luminescent salts to redirect light to strips of hotovoltaic panels.

7. INFLATABLE CONCRETE DOMES
By attaching concrete slabs around an airbag and then inflating it, researchers at the Vienna University of Technology can construct a dome in two hours.

8. 3D-PRINTED BRIDGES
Designer Joris Laarman and Dutch R&D firm MX3D are developing robot arms to move along bridges as they build them.

9. TALL-TIMBER
Rüdiger Lainer and Partners will begin construction of a 24-storey wooden skyscraper in Vienna next year. It will become the world's tallest residential timber building.



AN INTERNET OF FEMALE THINGS

Wearable-tech startups have finally noticed the female market, and are targeting it in ever more intimate ways. Here is WIRED's pick of three new fem-tech products loaded with sensors to quantify the female body's health. **RM**



ELVIE
A soft, egg-shaped "internal wearable" for pelvic-floor exercises. Squeezing Elvie is said to build strength in the muscles that control incontinence, which can often be damaged during pregnancy. Sensors measure the pressure, so users can get real-time feedback on the app. *£149, elvie.com*



LOONCUP
This smart take on the menstrual Mooncup is fitted with sensors to tell you when it's full, and monitors the fluid's colour to check for any anomalies. The crowdfunded device, which can be used for up to 12 hours, sends data to your phone, along with monthly updates. *$40 (£25) pre-order, kickstarter.com*



YONO
This in-ear thermometer measures basal body temperature (BBT), a person's lowest temperature, achieved during sleep. Ovulation hormones raise BBT, so having accurate night figures helps to pinpoint fertility. There's also a *YONO* companion app for personal analytics. *$99, yonolabs.com*

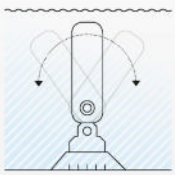


AUSTRALIAN SEA POWER

Designed to mimic the ocean's plant life, BioPower's bioWAVE wave-energy generator takes a dive when things get rough

THIS 400-TONNE, 23-METRE-HIGH WAVE-ENERGY GENERATOR IS inspired by floating strands of seaweed. "We designed it with a highly efficient pivoting structure, reminiscent of the natural swaying motion that a plant would undergo in the waves," explains Timothy Finnigan, CEO of Australian energy technology company BioPower Systems, which created the bioWAVE generator. This biomimetic approach not only helps the bioWAVE harvest wave energy more efficiently, it also keeps it safe in rough conditions. "Natural systems have evolved over billions of years to survive this difficult environment," explains Finnigan. "Kelp in particular can reach right up to the surface, where it moves with the forces rather than braces against them." Mimicking kelp, the bioWAVE lies down flat against the ocean floor during stormy conditions by filling its three large buoyant tanks, called blades, with seawater. When conditions are calmer, compressed air forces the water out, causing them to float back up.

"One of the key problems with wave energy has been that structures are focused around withstanding the most extreme waves that could possibly occur, so the design has been detached from the day-to-day purpose of generating energy in typical conditions," explains Finnigan. "That seemed illogical to us, so we designed our system to respond to the waves, rather than brace against them." A 250kW demonstration generator was completed in June for a trial off the coast of Port Fairy in Australia at the end of November. Next, BioPower systems plans to scale up to market-ready megawatt class design by 2020, producing around four times the prototype's power output. "Waves are a massive source of clean energy for the planet, particularly on the coastlines of Australia, Northern Europe and the west coast of North America, which are buffeted by a consistent, continuous supply," says Finnigan. "We know this technology can be made to work. The challenge is making it cost-effective." **Kathryn Nave**
biopowersystems.com



The proptype will operate at a depth of 30 metres

Digital extra!
Download the WIRED app to watch the bioWAVE in action



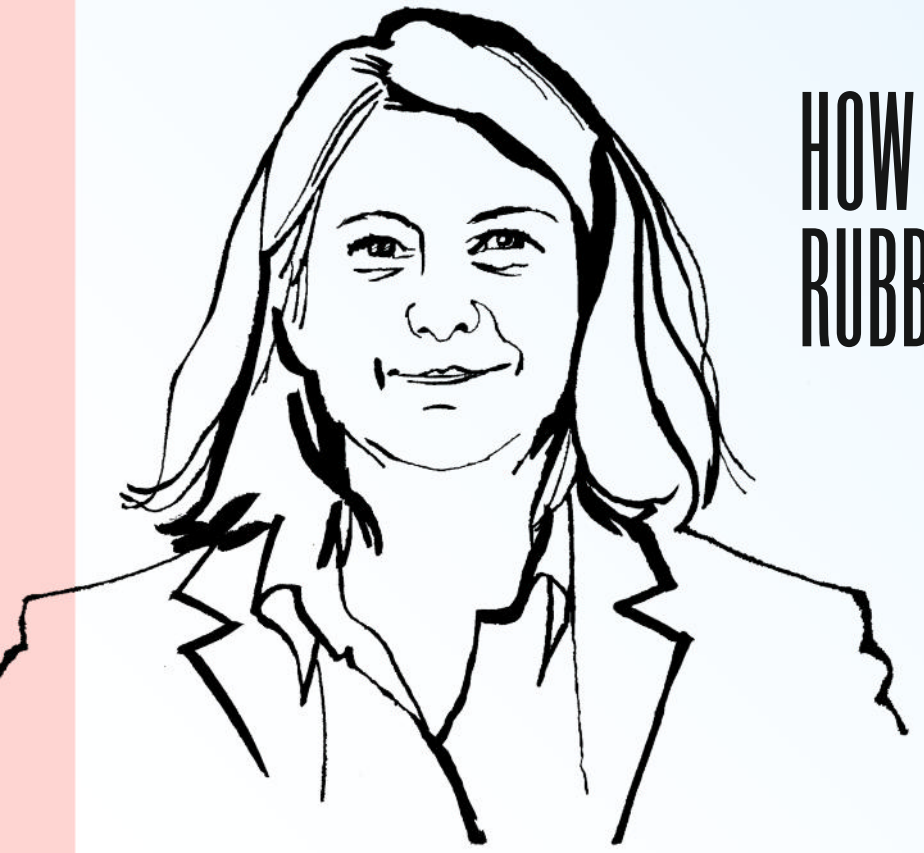
The Microsoft Cloud gives Special Olympics instant access to key performance and health data for every athlete, no matter where they are. Microsoft Azure and Office 365 help streamline the management of 94,000 events across 170 countries each year. So the focus can be on changing the lives of athletes, and that's the true victory.

This is the Microsoft Cloud.

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Microsoft Cloud

HOW WILL WE DEAL WITH RUBBISH IN THE FUTURE?



MARGARET BATES
PROFESSOR OF SUSTAINABLE WASTES MANAGEMENT, UNIVERSITY OF NORTHAMPTON

"It will be the householders' responsibility to pay for their waste. 'Pay as you throw' is internationally effective and likely to be the way to hit new EU recycling targets. Waste collections will be monthly at most. People will know the cost of waste and expect businesses not to pass waste on to them. There will be a reduction in the export of waste-derived fuels. People will know the value of their waste and expect it be used to generate heat, electricity and cooling. Those who flout the rules will be fined or imprisoned proportionately to the impact of their crime." **Gian Volpicelli**



PER-LAGE GÖTVALL
PROJECT MANAGER, VOLVO PROJECT ROAR

"Smart machines will help with a wide range of society's activities, because there will be a greater need for low-impact, safe and efficient movement of waste. Urban living will see an increased convergence of connected systems, vehicles and infrastructure – including the automation of waste collection. Our Project ROAR, for instance, will connect the waste-collection trucks' operating system with robotic waste-bin handling."



LUCA MENESINI
MAYOR, CITY OF CAPANNORI, ITALY

"The future of waste management is more dependent on the awareness of companies and citizens, and on the authorities' ability to convey the idea that the best way to manage rubbish is by producing less of it in the first place. We adopted this strategy by encouraging recycling and reusing on the one hand, and reduction of waste on the other. Recycling, reusing and reducing will bring about a 'circular economy' model that would allow us to attain a fully sustainable society."



NATE MORRIS
CO-FOUNDER AND CEO, RUBICON

"The answer to disrupting an antiquated industry with misaligned incentives is in transparency and competition: by empowering independent hauliers and recyclers to grow their businesses. A cloud-based platform connecting customers with a network of vendors will make diverting waste from landfills economically compelling. This will allow companies to reduce expenses, track metrics and render landfill obsolete. Sensors will collect data for better supply chain decisions."



KATHLEEN LIGOCKI
CEO, HARVEST POWER

"The future is organic waste – and it's at your fingertips. It's on your plate: the spicy pepper and discarded crust. It's on your chopping board: carrot tops, potato nubs and apple cores. And it's in your fridge: wilted lettuce, forgotten buns and that weird jam from Aunt Matilda. Organic waste can, through anaerobic digestion, be used to power homes and vehicles. Organic waste is a source of energy and nutrients that we currently send to landfills."

ILLUSTRATION: LUCINDA ROGERS



This cloud stands up to any storm.

Microsoft Azure scales to enable AccuWeather to respond to 10 billion requests for crucial weather data per day. This cloud rises to the challenge when the weather is at its worst.

This is the Microsoft Cloud.

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Microsoft Cloud

The hacker using YouTube to keep us safe

Samy Kamkar exposes the security flaws in everything from toys to car apps



IN AN AGE WHEN HACKERS trade techniques on the dark web and sell them to intelligence agencies, Samy Kamkar takes a more entertaining approach: YouTube. A display of the 30-year-old's digital mischief, the video series Applied Hacking teaches some 50,000 subscribers flashy hacks, and no household item is immune. He has tweaked a kids' toy to open garage doors, 3D-printed a lock-cracking robot, devised a fake charger that can sniff keystrokes in wireless keyboards, and even hijacked cars' smartphone apps to remotely unlock and start the vehicles. "I just assume everything is vulnerable," he says. "It's a pretty safe bet."

Kamkar gained notoriety in 2005 as the creator of the Samy worm, viral code that added unwitting MySpace users to his friends list and displayed the text "Samy is my hero" on their profiles. It worked too well, ripping through the site and bringing Kamkar a million new friends in 24 hours, along with a visit from very unfriendly Secret Service agents. He pleaded guilty to computer tampering and was banned from using computers for three years.

After that ordeal, Kamkar approaches his research with strict transparency. He says he alerts firms to vulnerabilities in their products but doesn't profit from his hacks and won't accept security consulting work, to avoid conflicts of interest. "I want to do what I think is right," he says. "That's hard when someone's paying you." Instead, he takes his reward from his modest fame – close to three million YouTube views so far – and the thrill of solving the hidden puzzles he finds in everything he touches. **Andy Greenberg**

Kamkar's Greatest Hits

SkyJack
A drone that lets a hacker take control of another drone.

Combo Breaker
A bot that can crack a combination lock in under 30 seconds.

OwnStar
A device that can be used to commandeer a vehicle through its smartphone app.

PHOTOGRAPHY: JULIAN BERMAN



This cloud opens one stadium to

450 million fans.

The Microsoft Cloud empowers Real Madrid to create a more personal connection with every fan from Madrid to Mumbai. Using Microsoft Azure, Dynamics CRM and Power BI, the team can deliver a unique experience that ignites everyone's passion as if they were all there.

This is the Microsoft Cloud.

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Microsoft Cloud

MAKE TECH HUMAN

THERE'S NO TIME LIKE THE PRESENT TO SHAPE THE FUTURE.

For the past nine months, Nokia and WIRED have been asking some of the greatest minds on the planet (including yours) what excites and worries them about where technology is taking us (or vice versa) and how we can shape that in a more human direction. And while this conversation raises as many questions as it answers, it's clear that the time to start talking about it is now.



"The real risk with A.I. isn't malice but competence. A superintelligent A.I. will be extremely good at accomplishing its goals, and if those goals aren't aligned with ours, we're in trouble."

STEPHEN HAWKING
THE STEPHEN HAWKING FOUNDATION



"While the Internet has made us a more globally connected society, it can also disconnect us from humanity—our own and seeing it in others."

MONICA LEWINSKY
BYSTANDER REVOLUTION



"I am concerned about losing our ability to experiment, disrupt the status quo, innovate, and rebel."

HOSSEIN MOIIN
NOKIA NETWORKS

POLLS:

Technology provides more people with access and opportunity. It also eliminates jobs and widens the wealth gap.

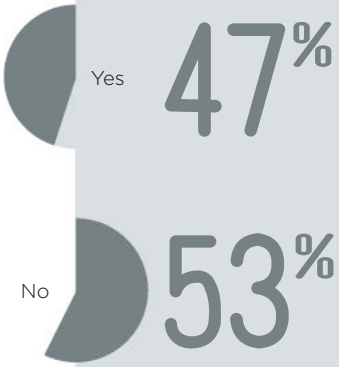
82%

say its benefits outweigh the downsides

39%

believe unlimited connectivity exaggerates differences instead of bridging the gap

Is privacy a thing of the past?



Monica Lewinsky Photo: James Duncan Davidson/TED

MEET THE #MAKETECHHUMAN 2015 AGENTS OF CHANGE

17 INFLUENCERS, ENTREPRENEURS, AND ACTIVISTS EXPANDING HUMAN POSSIBILITY THROUGH TECHNOLOGY



"The Web is not just a luxury, it is critical for people to really take part in society and education."

SIR TIM BERNERS-LEE
WORLD WIDE WEB FOUNDATION



"We need to inject humanism into our A.I. education and research by injecting all walks of life into the process."

FEI-FEI LI
STANFORD UNIVERSITY

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wired.com/maketechhuman
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NOTABLE COMMENTS

TED Talks
@TEDTalks

"Technology needs to be programmed with human values." What are those universal human values? Do they exist? #maketechhuman #TED2015

AGENT OF CHANGE
Chris Valasek
@nudehaberdasher

"Secret is out. @0xcharlie and I are human. #maketechhuman

On Reddit
reddit.com

"Am I the only one who thinks it's going to take a lot of work to get us from our current situation (basically surrounded by mid-20th-century technologies plus some devices) to a future that actually resembles a future? Going from smart phones to smart buildings etc will be monumental, in my opinion."

PRESENTED BY WIRED | ENABLED BY NOKIA

This program is produced by WIRED Brand Lab in collaboration with Nokia Corporation.


MASTRAFJORD
FLORØ
Fjord1
MASTRAFJORD

FJORD ESCORT

ON ANY GIVEN DAY, THIS FERRY MAKES UP TO 40 11-KILOMETRE TRIPS BETWEEN PORTS ON NORWAY'S WEST COAST, CARRYING TOURISTS, BUSINESS PEOPLE AND GOODS. IN MANY WAYS IT'S AN UNREMARKABLE VESSEL. HOWEVER, MASTRAFJORD AND ITS SISTER SHIPS ARE POWERED BY A REMARKABLE FUEL – LNG

PHOTOGRAPHY: CHRISTOFFER RUDQUIST



On a cool and misty western Norwegian morning, Captain Harry Mellingen-Haugland (*right*) eases *Mastrafjord* around the sea wall and slowly brings the ferry into dock. Despite its size, the 130-metre vessel is agile and surprisingly quiet, doing little to disrupt the calm waters of Boknafjord. From the ferry's bridge, Mellingen-Haugland has a 360° view of the stretch of water he crosses dozens of times a day.

Named after another nearby fjord, *Mastrafjord* shuttles between the tiny ports of Mortavika and Arsvågen. The 11-kilometre crossing takes around 20 minutes, with up to three ferries in operation at any time. Millions of people make the journey, which helps link the picturesque west-coast cities of Stavanger and Bergen, every year.

"It's the second-busiest ferry route in Norway in terms of vehicles and pedestrians," says Mellingen-Haugland, surveying the view from his captain's chair. "In the winter months it's mostly people who live and work in the area, as well as heavy transport. But during the summer months it's very much people holidaying in the fjords."

Efforts have been made in the area to use liquefied natural gas (LNG) as a fuel instead of diesel. *Mastrafjord*, and its sister ships *Stavangerfjord* and *Boknafjord*, were designed to run on LNG to reduce sulphur and NO_x emissions, as well as other particulates.

So, what is this fuel? LNG is a clear, colourless, non-toxic liquid which forms when natural gas – mostly methane, with other alkanes such as ethane, propane, and carbon dioxide – is cooled to -162°C. This process shrinks the volume of the gas by 600 times, making it easier to store and transport to markets around the world – either by pipeline, truck or shipping.

LNG gives off virtually zero sulphur emissions, particulates and nitrogen oxides, and can help reduce well-to-wheel greenhouse gas emissions. It has other benefits, too.

"For those of us working and operating LNG engines, it is very clean compared to other liquid fuels," says Peringe Rundhoude, chief engineer on *Mastrafjord*. "Inside the engine – inside the crankcase – it looks brand new when you open it. When you pull out pistons and cylinder liners for overhauling, you see the equipment is within new tolerances. Even with 50,000 hours of wear."

From his workstation just below the captain's bridge, Rundhoude oversees a strict maintenance schedule onboard the *Mastrafjord*, with spark cables, coils and pilot wells requiring refitting regularly. However, he can thank the work of Jeanine Klinkenbijl for the good-as-new appearance of his ferry's inner workings. As principal technical expert for fuel processing at Shell, Klinkenbijl oversees the processes that ensures hydrocarbons such as natural gas are at their optimum potential for use.

"There are a few drivers to what I do, such as safety and efficiency," she says. "If there are sulphur deposits, we can remove them and turn them into elemental sulphur for asphalt or fertiliser. If you have CO_2 it can be used for enhanced oil and gas recovery, or it can be stored using carbon capture and storage."

But Norwegian passenger ferries like *Mastrafjord*, *Stavangerfjord* and *Boknafjord* aren't the only vehicles powered by LNG. In 2013, Shell launched the first 100 per cent LNG-powered tank barge. *Greenstream* – built and designed at Peters Shipyards in the Netherlands

"FOR THOSE OF US OPERATING LNG ENGINES, IT IS VERY CLEAN COMPARED TO OTHER LIQUID FUELS"



and managed by the Dutch-based Interstream Barging – and its sister ship *Green Rhine*, are in service on the Rhine. Today, Shell Shipping & Maritime manages 44 LNG carriers – around 11 per cent of the world's LNG fleet – making Shell one of the largest LNG carrier operators.

Elsewhere, LNG is being used in the heavy trucking industry. In October 2015, Shell opened its fourth LNG truck-refuelling station in the Netherlands. The Amsterdam-based station is located in the western port area, a location with significant turnover from ships to trucks that distribute goods into the city.

"This business is emerging and it's early days," says Thomas Chhoa, who leads business efforts on LNG in transport at Shell. "We are committed to LNG as a fuel option, but it will take time to develop this market. Certainly in Shell we are investing in both the marine, and heavy-duty road transport sector to provide customers with this cost-competitive and cleaner burning fuel."

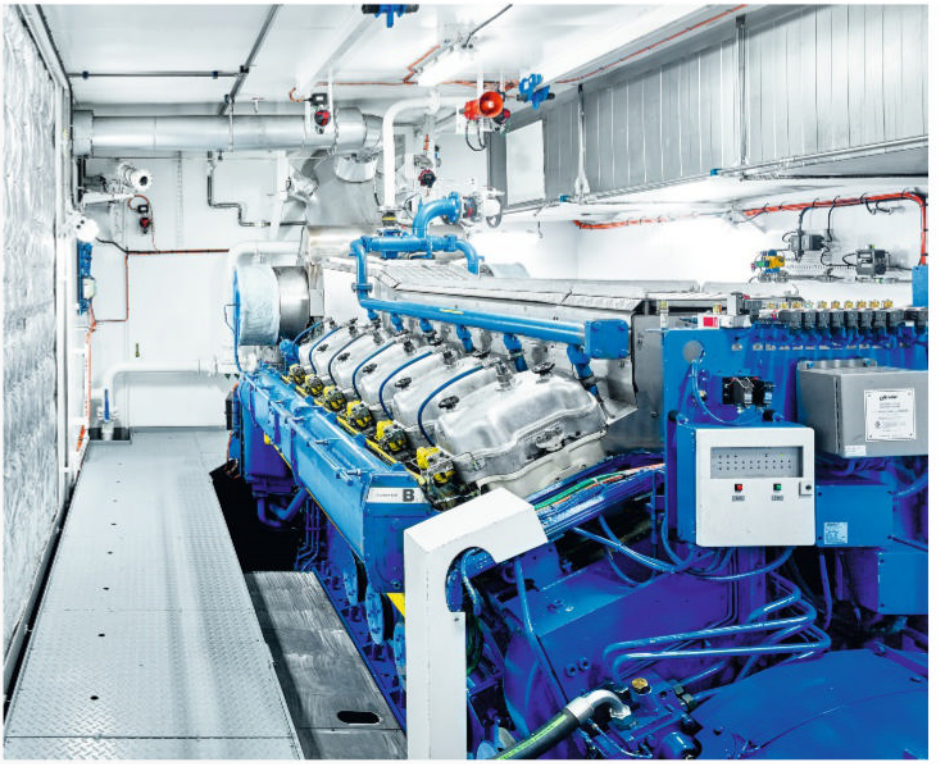
The three ferries of Mortavika-Arsvågen are certainly doing their bit. Since 2007, *Stavangerfjord* and *Mastrafjord* (*Boknafjord* launched in 2011) have each made up to 41 journeys a day, linking Norway's third-largest city with the country's tourist hotspot.

In the long winter months, it's dark when the ferries set out in the morning, and night will have fallen long before they make the final journey of the day. But these boats will continue to make their short, regular voyages, helping to keep families connected, businesses running and travellers moving forward to the next part of their Nordic adventures. ***For more, search #makethefuture***

Clockwise from top: Mastrafjord **captain Harry Mellingen-Haugland; the engine room; below deck; outside the engine room**







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WIRED LOVES

GEAR

This colourway was produced in limited quantities for the 2015 London Design Festival



KEF MUO
In 2008, KEF introduced the Muon speakers. They were limited-edition aluminium obelisks, sculpted by industrial designer Ross Lovegrove, and they cost £140,000 a pair. The MUO may lack a consonant, but the original ethos, concept, material and designer remains, as does the unrivalled audio and build quality. Based around advanced twin 5cm drivers, it's easily the most impressive portable Bluetooth speaker WIRED has heard.
£299 kef.com

FETISH

WORDS: CHRIS HASLAM. PHOTOGRAPHY: MITCH PAYNE

The narrow toe box needs an extra half-size to accommodate wide fittings, so there's some lateral roll



SALOMON SPEEDCROSS 3 GTX

With a serious 10mm heel-toe drop and the deepest lugs on test, the Speedcross 3, at 340g per shoe, is the standout performer across soft ground. Wet Welsh slate proves more of a challenge and the outsole's chevron-shaped grips are vulnerable to snagging on hard, edged surfaces. The Gore-Tex water resistance makes these an ideal option for walkers or slower runners. ***7/10*** *£125 salomon.com*



MERRELL ALL OUT CHARGE

There's nothing spectacular about the Merrell, but in terms of weight (283g), ride and grip, it bests some of the higher-spec shoes here. The 6mm drop covers 12km of varying terrain quickly and in comfort. A snug upper and inner, and solid rubber protection around the toe, inspire confidence down tricky descents, and the UniFly sole delivers admirable shock absorption. ***7/10*** *£95 merrell.co.uk*



SAUCONY NOMAD TR

The PWRTRAC outsole copes well on many surfaces, particularly grass and gravel, making these ideal for woodland or urban trails, and they're adept at coping with sharp changes in direction. The lightweight seamless upper and midsole (the shoe is 261g) make for a cloud-like ride – the best here – at the expense of some stability. ***6/10*** *£90 saucony.co.uk*

HOW WE TESTED

Each shoe was assessed for comfort, protection, durability, stability and grip, in both the wet and dry, over many surfaces, including the Ryd Dhu path to the summit of Mount Snowdon, and the Man v Horse race in Llanwrtyd Wells. WIRED also racked up over 350km on forest trails, mulched park circuits, marshland and paths in east London, during a three-month, all-weather test period.



A large toe box – like the Mizuno's – makes this shoe ideal for wide feet

INOV-8 RACE ULTRA 270

This 270g stripped-down, versatile racer has a minimal 4mm drop and compressed EVA midsole. It provides excellent stability at the expense of some ride comfort and protection. The shoe is ideally suited to those who prefer a more connected, natural feel and technical, rocky terrain. ***7/10*** *£110 inov-8.co.uk*



MIZUNO WAVE MUJIN 2

Despite the bulk and weight – 325g – the Mujin 2 feel incredibly fast: WIRED achieved a 5km personal best down a treacherous, nettle-strewn path. Traction in the wet is excellent on soft and medium ground but less assured during climbs up hard, loose-grit paths. The quality build, premium comfort and outstanding stability more than justify a hefty price. ***8/10*** *£115 mizuno.co.uk*

WORDS: DUNCAN BAIZLEY.
PHOTOGRAPHY: MITCH PAYNE; ROGER STILLMAN

TEST

Running roughshod

WIRED hits the mountains to find the toughest trail shoes

Adidas's now ubiquitous sole tech originated from the packing material used in BMW car dashboards





ADIDAS TERREX BOOST

A deep-lugged, Continental rubber outsole and tough construction make the Terrex Boost appear much heavier than they are (325g). Grip on soft ground is exceptional and concerns about durability are dispelled by hard ground and road work. The fit is narrow and WIRED suffered rubbing – the speed lacing in particular needs a rethink. ***6/10***

£120 adidas.co.uk



The larger of the weathervanes is one metre tall on a 10cm-diameter birch wood base

1

2

3

1. KNEIP WEATHERED
Design duo Kneip use atmospheric changes to alter the properties of their creations. The steel, copper and brass Breeze weathervanes oxidise over time, creating intricate patinas, as does the Pat. vol 1 sculpture (*shown in front*). *From €925 kneip.no*

2. SERPENTINE STEREO
Osloform finds lux uses for industrial materials: its brass-fitted Serpentine stereo uses Valchromat, a resin-bonded, dyed wood-fibre panel. Inside are two 50W single-ended Class D amplifiers from ICEpower, an RIAA phono preamp, and 10cm Tang Band bamboo-paper-cone drivers. *€3,860 osloform.no*

3. TREFJØLA MONTEREY
Reclaimed rarely looks this fresh. One of dozens of Trefjøla's forward-thinking chopping-board designs, each Monterey board is crafted using rescued materials – in this case, teak from a 1952 San Francisco-based cruise ship, which somehow ended up at a breaker's yard in Olso. *From €90 trefjola.com*

WORDS: CHRIS HASLAM. PHOTOGRAPHY: MITCH PAYNE

FETISH

Scandinavian style for every surface

Functional and beautiful products from the finest in new Norwegian design



4. KI LIGHT
With a slim form that echoes the plants it helps, the KI light by designer Hallgeir Homstvedt for Elementa gives indoor greenery a winter boost. The lamp is available as either a stem to push directly into your plant pot, or with a pot-sized marble base. Its magnetic shade can be adjusted in height and angle.
£poa elementa.no

5. BLOSSOM TABLE MIRROR
This Andreas Bergsaker flowerbed-inspired Blossom vanity set reinvents the dressing table. Its two mirrors are removable, and the central LED lamp can be adjusted. The milled beechwood tray keeps all your bits organised.
£poa andreas bergsaker.com

6. DUPLÉ SIDE TABLE
Duplé is an attempt to create multi-function furniture. Using an oak top – a traditional, interiors-friendly material – designer Alexander Åsgård has matched it with a steel tray and reinforced legs, so the piece can work as both a delicate side table and a robust stool for everyday use.
£poa alexander aasgaard.com

4

6

5

The smaller, magnifying mirror is 120mm in diameter; the large, flat one is 160mm

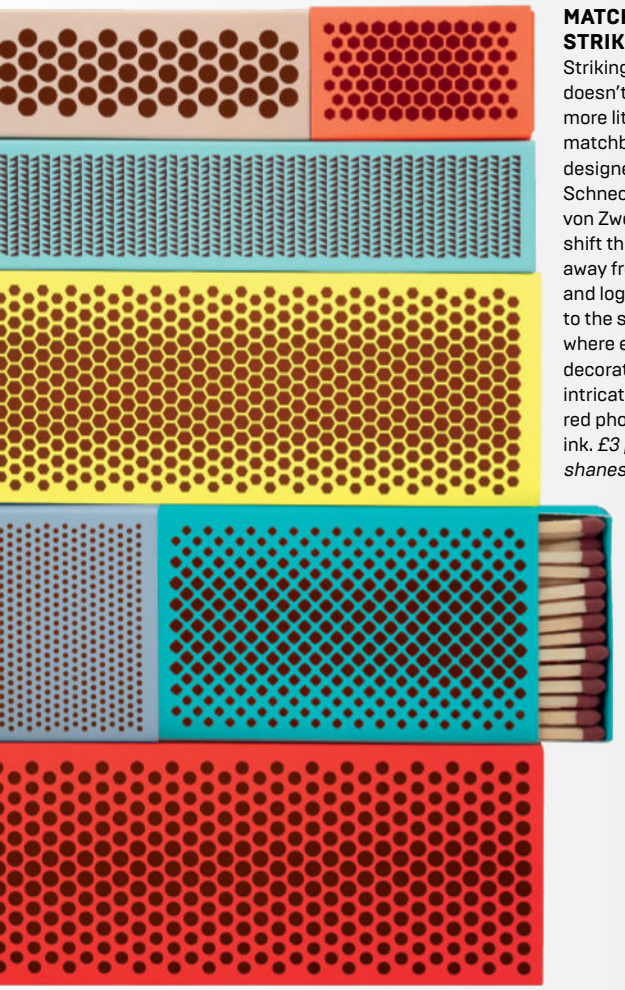


SPEETBOX BY S+ARCK
This fully scalable heating system has been designed in conjunction with Philippe Starck. It centres around a supremely efficient wood-burning cube that produces 150 times less dust than an open fireplace. Flank either side with a stone-filled box – the rocks absorb heat and act like a radiator long after the fire has gone out – and add in a seat or a log store to create your own wall of warm. *£poa (ordering now) speeta.com*

The electronically controlled stove has a 5.5kW heat output

Burning desires

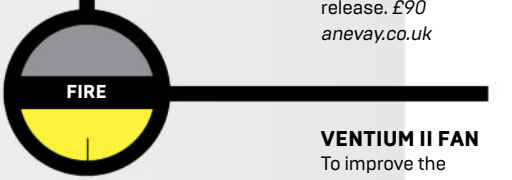
WIRED gets hot and bothered with the finest in incendiary design



MATCHBOXES STRIKE
Striking design doesn't come more literal. These matchboxes, designed by Shane Schneck and Clara von Zweigbergk, shift the focus away from ads and logos, and on to the strike pad where each box is decorated with an intricate pattern of red phosphorous ink. *£3 per box shaneschneck.com*



ANEVAY HORIZON
Made in South Africa, this provides safe, smokeless cooking in areas where respiratory diseases, caused by inhaling solid-fuel smoke, kill more than malaria does. Efficient, lightweight and safe to move, even during cooking, it has a combustion efficiency of 96.7 per cent. This means that harmful gasses are burned before release. *£90 anevay.co.uk*





VENTIUM II FAN
To improve the heat distribution and efficiency of a wood-burning stove, this anodised fan uses Peltier technology to turn the heat generated from the stove into electricity to power the fan. Once turning, it requires a temperature of 45˚C to work. The blades push warm air and help to heat more space per kW of energy. *£85 valiantfireside.com*

Using no mains electricity, the fan runs almost silently

WORDS: CHRIS HASLAM. PHOTOGRAPHY: DAVE LIDWELL; RASMUS NORLANDER



A laptop that erases borders, starting with the display.



It's the world's smallest 13-inch laptop, but that's only the beginning. With the Intel® Core™ processors, Windows 10, a virtually borderless InfinityEdge display with an UltraSharp™ Quad HD+ option, and amazing battery life, XPS 13 is designed to outperform the competition in every category.

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WIRED LOVES



The Panono can store more than 600 photos with its 16GB of memory

FETISH

PANONO CAMERA
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€1,499 panono.com

WORDS: CHRIS HASLAM.

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oppodigital.co.uk



TRAKTOR DJ APP

No extra hardware needed here – just plug an iPad running TRAKTOR DJ into your sound system. This software delivers equalisation and live FX control in virtual form, but for real buttons, it syncs with a controller such as the TRAKTOR KONTROL S4 MK2 (£399). **8/10** *native-instruments.com* **Hardware:** £559 **Software:** Native Instruments Traktor DJ (£7.99)

DENON DJ MC6000 MK2

"It feels like you're doing two things at once, as there's no display," says Phil Faversham, with his eyes fixed on the laptop to the side. "But the build does feel that bit sturdier than the Numark." Although useful, the assignable FX per channel feels less integrated with Serato DJ, causing timing issues. **6/10** *denondj.com* **Hardware:** £399 **Software:** Serato DJ (free)

Digital DJ delights

Four semi-pro mixers battle for a spot on WIRED's set list



HOW WE TESTED

WIRED visited the iconic Ministry of Sound club in London to test four leading DJ controllers using The Box, the club's state-of-the-art main-room sound system. Overseeing events was Phil Faversham, Ministry of Sound's club development director and the man behind Ministry of Sound Audio (ministryofsound.com/audio). Ease of use, build quality, technical capability and how well the bedroom-DJ kits worked in a professional context were all assessed.

SOFTWARE

The world of DJing has evolved from vinyl, to CDs, to hardware controllers used to run files via a laptop, USB stick or tablet. The pro DJ software used here falls into three main camps: Pioneer rekordbox, Serato and TRAKTOR, run from WIRED's iPad Air 2 and Apple MacBook Pro 13-inch to ensure ample processing power. Each item on test offers auto-sync, full pitch control, cue points, samples, looping, built-in FX and key recognition – all best exploited when paired with a hardware controller.



NUMARK NV

"The jog-wheels here are too finicky," notes Faversham of the Numark's flimsy build and cheap faders with tops that come off. But there are some standout tricks, such as knobs that can activate assigned FX, only when physically touched. "That's seriously cool," says Faversham. The layout is also a little tight between the four channels, but the dual-screen setup means your laptop needn't be front and centre. **8/10** *numark.com* **Hardware**: £499 **Software:** Serato DJ (free)

WORDS: MIKE LOWE. PHOTOGRAPHY: MITCH PAYNE; DAVE LIDWELL.

PIONEER DDJ-RZ

One of the first wave of rekordbox products, this is Pioneer's kit for a laptop-based setup, to compete with TRAKTOR and Serato – but it's missing a display and USB inputs. "The model below this [the DDJ-RX] has USB and a display – so why not here?" asks a puzzled Faversham. However, its world-class CDJ jog-wheels and a pro-quality mixer make this the best in our test group. **9/10** *pioneer.co.uk* **Hardware:** £1,549 **Software:** rekordbox DJ (included)

TEST



Built-in effects include horns and sirens, and you can load and manipulate your own

Panasonic

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1. SUNGLASSES
Available in five styles (Scout shown), these Fanoptics shades are limited to 100 pairs, all made and designed in the UK. The frames are Solidwool with Carl Zeiss lenses. *£320 fanoptics.co.uk*

2. KNIFE
Ben Edmonds crafts his blades in Derbyshire using the finest carbon steel. His limited-edition 25cm kitchen knife has a full tang and a hard wearing Solidwool handle. *£320 blok-knives.co.uk*

Knit picks

Solidwool, a versatile material created from unwanted fleeces, is bringing a tough texture to design



4. CHAIR
Partner to the side table, the Hembury chair is inspired by the moulded Eames chairs of the 50s. A powder-coated steel frame adds rigidity to a Solidwool seat and ash legs. *£395 solidwool.com*

3. TABLE
Sheet Solidwool is idea for furniture. The flat surface of the Hembury side table shows off the natural variation in the material; the legs are locally sourced ash. *£245 solidwool.com*

FETISH

MADE WITH WOOL

Blending bio-resin with coarse, dark wool from Herdwick sheep in the Lake District, Devon-based Solidwool has created a tough, versatile, fibreglass-like material.

WORDS: CHRIS HASLAM. PHOTOGRAPHY: MITCH PAYNE

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Smooth operators

WIRED tackles tough tufts with intense pulsed light groomers

TEST



PHILIPS SC2006/11 LUMEA PRECISION PLUS

This design comes with two emitter heads: a small one for use below the cheekbone on sideburns, upper lip and chin, and a larger one for the body. Five intensity settings cater for a range of skin types. It's the largest and heaviest device, but, "It is easiest to hold, and its main flash window is quick to use on large areas of the body," says tester Rosie Asfa. "After eight weeks, I found a few hairs in the test area, but they're very fine and soft." **9/10** *£450 philips.co.uk*

Charging time 100 mins **Operation** 370 flashes in one charge **Test area time** Five secs **Eight-week hair regrowth** 1mm

HOW WE TESTED

WIRED enlisted the help of 26-year-old Rosie Asfa to try out three intense pulsed light (IPL) hair-removal devices, over the course of eight weeks. Each IPL unit was tested on a 4cm x 4cm patch of arm and rated for ease of use, performance and versatility. At the end of the eight weeks, hair growth was measured and the surface assessed to see which was most effective.



The IPL2000 can flash every five seconds



REMINGTON IPL2000 I-LIGHT REVEAL

This model can be used below the cheekbones, as well as on the body. A 15-minute rapid-charge function gives 20 flashes – useful for quick touch-ups. But having the smallest flash window in the group means it takes longer to cover the same area. After eight weeks, hair regrowth was visible, but the texture felt smooth. **7/10** *£199 remington.co.uk*

Charging time 110 mins **Operation** 100 flashes in one charge **Test area time** 20 secs **Eight-week hair regrowth** 2mm

PANASONIC ES-WH80

At 341g and 20.8cm long, Asfa was impressed by this model's lightweight, slimline body and large 3.5cm-wide flash window. "It's easy to hold and set up – just click and go," she says. Battery life is impressive and it's faster to use than the Remington. It can cover a large area of the body, but, unlike the others on test, it can't be used on the face. After eight weeks, hair regrowth was minimal. **8/10** *£350 panasonic.co.uk*

Charging time 180 mins **Operation** 600 flashes in one charge **Test area time** 10 secs **Eight-week hair regrowth** 2mm

WORDS: EMILY PECK. PHOTOGRAPHY: MITCH PAYNE; ROGER STILLMAN

D7200

24.2 MEGAPIXEL

51 FOCUS POINTS

ISO 100-25600 ISO RANGE

BUILT-IN WIFI



AMBITION IN FOCUS

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Photo © Andrew Hancock

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Nikon

At the heart of the image

WIRED LOVES



I

The set's serif-font "I"-shaped profile provides a sturdy base, a flat shelf on top, and its name

SAMSUNG SERIF

With a design that recalls the days when sets were significant pieces of furniture, this Samsung TV is a rare thing: a quirky designer collaboration that has made it to market. Created by Ronan and Erwan Bouroullec, the wide-based Serif can be placed without a stand or on screw-in legs, and keeps all its rear ports and cables tidied away behind a fabric screen. It's available in white, black or blue, and in 24" and 32" HD, and 40" UHD. *From £599*
samsung.com

PHOTOGRAPHY: MITCH PAYNE. WORDS: CHRIS HASLAM. INSET: DISNEY/LUCASFILM

A vision of tomorrow

Test Lab inspired by Telefónica Open Future at the WIRED2015 exhibition featured some of the most exciting products around





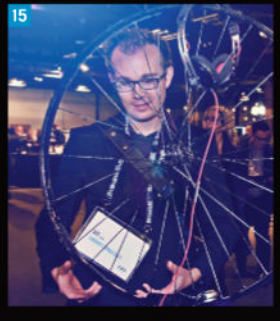












Glimpsing a blue whale is unlikely to have been on the list of expected activities for a lot of WIRED2015 delegates. But with multiple virtual- and augmented-reality kits on display at Test Lab inspired by Telefónica Open Future, attendees were transported to multiple new worlds – including a sunken shipwreck.

"WIRED2015 in London is a highlight for Telefónica," says Ana Segurado, director of Open Future at Telefónica. "And this year we were honoured to be able to bring companies and people over from Open Future, our entrepreneurship and innovation area."

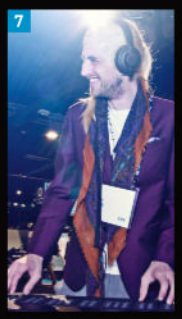
Among the Open Future exhibitors at Test Lab was GiveVision's augmented-reality glasses. Designed for people with visual impairment, the system describes the wearer's surroundings via an audio feed. It can read newspapers, notify which bus is approaching and dictate food labelling. Also from Open Future was Smartdrone's industrial-sized UAVs, which are able to detect oil leaks at sea or pest outbreaks in fields, and FirstVIsion's wearable broadcast system, which, embedded in a shirt, can film sport from a player's point of view.

"There were so many exciting concepts, gifted thinkers and inspiring microbusinesses," says Segurado. "It was with pride, then, that we were able to present just a small selection of companies we're helping to accelerate."

Elsewhere, Ducati showcased its new Scrambler motorbike (with WIRED detailing), NERF brought along its latest line of soft projectiles and Roli demoed its keyless digital pianos. Almost too many WIRED toys for one room – almost.

























Test Lab inspired by Telefónica Open Future

1 FirstV1sion
2 PlayStation VR
3 Technology Will Save Us
4 GiveVision
5 Hyve Icaros
6 Fove
7 Roli Seaboard
8 Ebove B/01
9 DiscoDisco
10 GiveVision
11 Ducati Scrambler
12 HTC Vive
13 Networking
14 Networking
15 Moogies
16 Interoute
17 Can-Am Spyder F3-S
18 Alchemy VR

Visit openfuture.org/en or youtube.com/digitalfutures

TELEFÓNICA – ON STAGE

Alex "Sandy" Pentland (*below*) helped create MIT's Media Lab, the Media Lab Asia, and the Center for Future Health. He chairs the World Economic Forum's Data Driven Development council, is academic director of the Data-Pop Alliance, and is on the advisory board for Telefónica – including the Data Transparency Lab, which Telefónica helped to create and continues to develop.

That subject of transparency was the basis of his Main Stage talk at WIRED2015. "Today, 80 per cent of people, including kids, own a phone. Those phones are sensors," he told the audience. These sensors leave behind a trail – of "digital breadcrumbs". By following those trails you can identify the poverty, mortality and even crime rates of a given area. This, he says, gives citizens the ability to evaluate how well governments' digital policies and initiatives are being implemented.

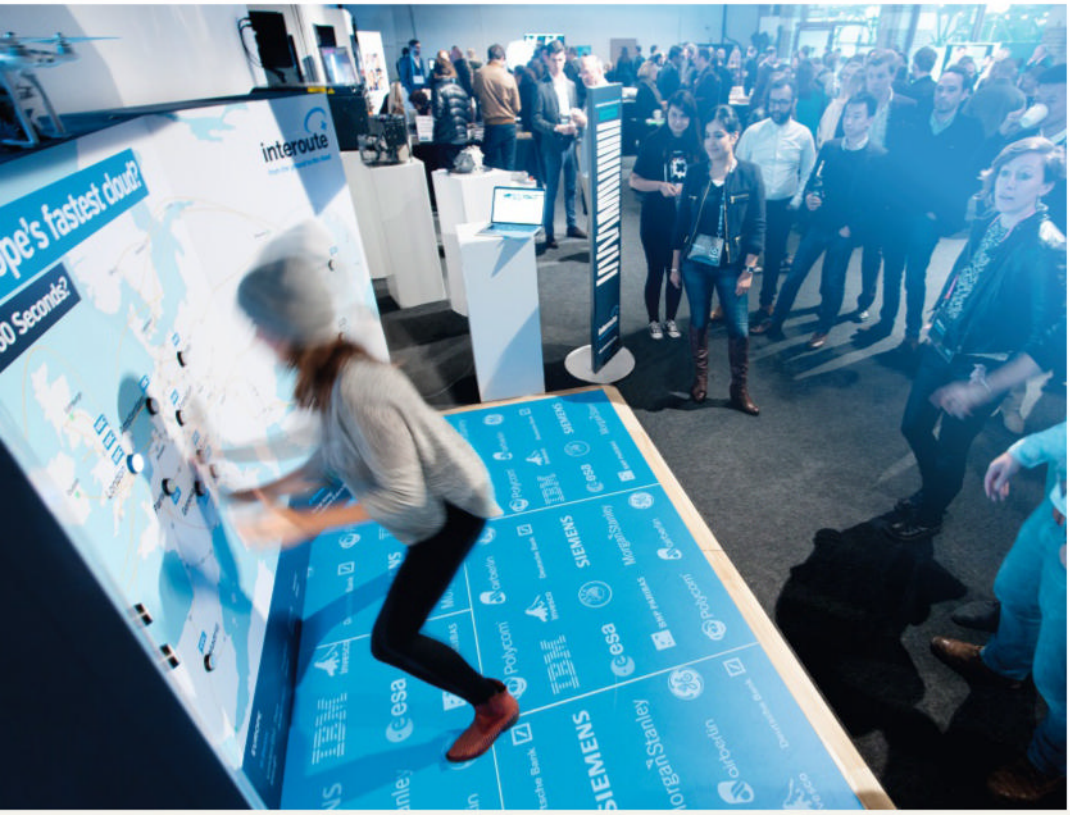
"For the first time you can imagine a world where there's real transparency and accountability of how things are working out," he said. There might be an element of nervousness about opening up personal and public data for analysis, but for the uses suggested by Pentland, it's not what people say or do that matters, but the "patterns of interaction".

A recent market study by Telefónica, entitled *Personal Data: The People's Perspective*, found 25 per cent of people are sceptical that the "good things" – such as political transparency – will result from data analysis, and are concerned they will be outweighed by the bad. So Pentland is helping to set up the Data Transparency Lab. "Data is powerful, data is valuable," he said. "We don't know where it's going. And we've got to find out."



Race the data

Interoute owns the fastest cloud service available, as demonstrated at WIRED2015. This speed isn't just for fun – it's crucial for the coming developments in business



Data travels quickly. Very quickly if it's utilising Interoute's global cloud platform. That's a fact WIRED2015 attendees discovered when they "raced" the cloud services provider in delivering data across the globe (*left*).

The installation was just for fun, but it illustrated Interoute's point. Its Virtual Data Centre (VDC) is the fastest transatlantic cloud service, and that matters to companies shifting workloads to the cloud.

"We're massive users of the cloud," said Antoine Blondeau, CEO of AI platform Sentient Technologies, at a WIRED2015 breakfast discussion on the future of work. "What we do is tap into 4,000 sites globally – that's between two or three million CPUs – a huge amount of computation."

It's a trend we're going to be seeing more of, if discussion at the panel is to be believed. Chaired by WIRED Consulting director Sophie Hackford, the talk also included Interoute CTO Matthew Finnie, and WIRED contributing editor Daniel Nye Griffiths.

The debate covered the growth of AI, the death of the physical office, the intelligent Internet of Things and autonomous machine workforces – all developments built on the cloud.

For Finnie, the power of the cloud lies in how it makes resources more available for every type of business.

"The cloud is enabling people to try out the things they want to do in a very efficient way," he says. Interoute's ground-to-cloud service offers the same computing power and storage capacity to one-man startups and giant organisations – such as UEFA and the European Space Agency – alike.

This could have huge implications, allowing established players and disruptive startups to flourish. It may even herald the end of work as we know it, as we all become cloud-based digital nomads.

For more info, see interoute.com

PHOTOGRAPHY: MICHAEL PALEODIMOS

FROM GROUND TO CLOUD

Interoute is the owner-operator of Europe's largest network and global cloud services platform, an integrated infrastructure of over 70,000 route kilometres of fibre, 12 data centres, 14 virtual data centres and 31 colocation centres, with connections to 195 partner data centres. Its full-service unified ICT platform serves startups and international Enterprises, as well as major European telecommunications service providers, internet giants, governments and universities. Interoute is at the forefront of cloud services, delivering virtualised services across its network and data centres. Today, more than 70 per cent of Interoute's business comes from enterprises and 30 per cent from wholesale customers. Clients include football organisation UEFA, trading platform Saxo Bank, global tailor Scabal and the European Space Agency.









Inset images: **Delegates attend The Future of Work discussion; a guest tries out Interoute's Test Lab installation**

WIRED 2015

THE OFFICIAL REPORT

BY KATHRYN NAVE

PORTRAIT PHOTOGRAPHY: NICK WILSON

Every October we bring alive the magazine's stories and voice in a two-day live event at Tobacco Dock in east London. At WIRED2015 we brought together more than 50 speakers among 500 delegates to explore the issues, trends, debates and bold thinkers shaping tomorrow's world. And what a group of impressive storytellers: Nadezhda of Pussy Riot, the team at Noma restaurant in Copenhagen, musicians curated by Denzyl Feigelson from Apple Music, specialists in artificial intelligence, gaming and nutrition...

On the third day we invited teenagers to WIRED2015: Next Generation for an inspiring series of talks and workshops. You can catch all the presentations at wired.co.uk/wired2015.

On the next few pages, with thanks to all the people who participated, are some highlights. David Rowan

"There's a saying about not sweating the small stuff. Happiness is in the small stuff."
– Paul Dolan, happiness scientist



Nadezhda Tolokonnikova

Artist, activist and musician

Nadezhda Tolokonnikova, of Moscow-based activist punk collective Pussy Riot, doesn't believe in international barriers. "I'm a nomad – I live without borders," she said from the stage. "The global economy knows no borders. But governments are much slower, they lag behind." Pointing to the refugee crises in Europe, the topic of Pussy Riot's latest music video, she highlighted the example of more than 10,000 Icelandic citizens who opened up their homes to house Syrian refugees following their government's announcement that the country would accept only 50.

"We must not wait for our governments, but take control ourselves," said Tolokonnikova, who is now working with Cambridge students to build refugee shelters in Calais. "We must create networks and use technology to do what governments can't."

Alongside fellow band member Maria Alyokhina, who also spent 18 months in prison for Pussy Riot's 2012 anti-Putin protest, Tolokonnikova is setting up an NGO to help prisoners and those who've suffered police injustice. "Digital technologies are a huge part of our work," she explained. "We are creating a map of all the prisons in the world. We've already collected information on each Russian prison, and we want to include US prisons, because some are even worse than in Russia. It will shame US politicians and shine a light on Scandinavian systems, which we believe are the best in the world."

Jacob Whitesides

Social-media music star

As with many musicians over the years, Jacob Whitesides' story began with a girl he was trying to impress. Unusually, the quest – initially successful – led him to gain 1.8 million followers on Twitter, launch a record label and complete a sold-out European tour – all before he turned 17. "I partnered with BMG earlier this year, but before then it was just me and social media," said Whitesides. "This has really been driven by the power of creating relationships with fans since the beginning."

Although few musicians set up their own label, Whitesides believes every artist should keep close control of their brand. "You see so many artists coming up through YouTube who build very personal relationships with their fans, but as soon as they sign over they lose that control and their pages become inorganic," he explained. "Fans can see right through that."

Whitesides' own fan base gave him the leverage to go into negotiations with labels on his own terms. "It's so much easier now to get your music out to the world," he said. "All you need to post a video is an iPhone. The relationship has changed and labels need artists more than artists need them. That's enabled all those who would have never had the chance ten years ago."

"I started with a computer webcam and a $100 [£65] USB mic – it's such an opportunity for new artists to create music foundations without a big label."

Josh Tetrick

Food innovator; CEO and founder, Hampton Creek

To change the world, you need to go after an entire system, Hampton Creek founder Josh Tetrick told the WIRED2015 audience – an understanding he came to realise three years ago when trying to help Liberian street kids into education. "I wasn't changing things in a transformative way," he said. "I decided I wanted more than incremental change. I wanted to attack a whole system."

Tetrick decided to take on food, starting with the egg. "Most of the food out there is shitty for the body and shitty for the environment," he said. "Yet there are 400,000 plant species – 92 per cent of which have never been explored." By analysing the molecular structure of these plants, his startup Hampton Creek aims to identify those that could replace traditional food ingredients. The Canadian yellow field pea, for instance, has emulsifying properties that make it an ideal egg alternative.

This discovery formed the basis for its first product, Just Mayo, an egg-free mayonnaise substitute. Stockists include 7/11, Walmart and Costco. But not everyone's a fan. In 2014, Unilever, owner of Hellmann's, brought an unsuccessful lawsuit against the company for false advertising, and in August, the US Food and Drug Administration told Hampton Creek that an eggless product could not be classified as "mayo".

Tetrick, who is "optimistic" about keeping the name, sees the response as an inevitable consequence of Hampton Creek's encroachment on to the territory of the big manufacturers. "The trap for us is being framed as a nice little product for Californian vegans," he said. "Our philosophy is that the thing that's better for the planet must be accessible, even to those living on welfare."



Jose Miguel Sokoloff

Taming guerrillas with marketing

In December 2010, a Black Hawk helicopter flew into the jungle stronghold of the Revolutionary Armed Forces of Colombia (FARC), a guerrilla organisation that had terrorised the country for more than 50 years. On board: some Colombian Special Forces and a few thousand fairy lights. Jose Miguel Sokoloff, president of marketing agency Mullen Lowe Global Creative Council, is the man who sent them there – in partnership with the Colombian government's peace negotiation team.

"We covered nine trees in the jungle with Christmas lights," he explained. When motion sensors near the trees were activated, the lights displayed the message: "If Christmas can come to the jungle, then you can come home." By January 25, 331 guerrillas had demobilised – about five per cent of the guerrilla force. Other campaigns included posters displaying childhood photos of activists with messages from their mothers saying: "Before you were a guerrilla, you were my child."

Since the campaigns began, more than 18,000 guerrillas have demobilised, including FARC's chief bomb maker. In 2012, they were forced to the negotiating table – the Colombian government now expects a resolution within six months. "We want to achieve peace," says Sokoloff. "We need to achieve peace to move Colombia to the next step."

"Guerrillas are as much a prisoner of their organisations as those they hold hostage. We reminded them of the power of emotions."



Hyeonseo Lee

North Korean defector

As a girl, Hyeonseo Lee awoke one night to find her family home burning around her. As she and her brother recovered outside, their father dived back inside the house to rescue the family's most important possessions: "Pictures of two dictators – requirements for every North Korean home," Lee said. "None of us thought this strange. If he failed to save them, we would have been punished."

This is just one example of many absurdities of life in the Democratic People's Republic of North Korea. Yet it took Lee's escape from the country in 1997 aged 17 for her to gain perspective on the situation in her homeland.

"My mum trained me since I was young never to say anything bad about the system," she said. When Lee's friend's father was heard saying, "The system is unfair", his family disappeared overnight. Citizens are forced to watch public executions of such "criminals" from a young age. Lee saw her first at seven.

Though she finally reached South Korea in 2008 after spending nine years in China, Lee's escape did not bring her true freedom, as her family remained behind. "Convincing my family to follow me to freedom was very difficult," she said. "I felt so guilty tearing them apart, but I was so depressed without them. This is the unthinkable choice that North Korean defectors are forced to make. Family or freedom? Why can't we have both?"

Avi Yaron

Medical-device builder



Twenty-three years ago a young Avi Yaron was running two successful startups and life was sweet. "I had the Midas touch," he said. "I slept two to three hours a night and I was high on life." Then a motorcycle crash led to a brain scan and the discovery that he had a brain tumour. "It was like a bomb had dropped," he said. "They told me I must be operated on immediately."

Yaron decided instead to change his lifestyle. "I cut down from ten cups of coffee a day to two and decided to sleep for four hours a night," he said. But the tumour kept growing, so he gave in to a removal operation. Despite a successful recovery, 18 months later he was told that a residual tumour still remained, and it was too deep for more surgery. The necessary camera technology did not exist. So Yaron decided to create it.

"I spent two years studying camera technologies and invented a miniature chip, based on a fly's eye, that can produce a stereoscopic image," he said. "This can be fitted into a scope and inserted into the brain, enabling tiny entrances to deep-seated lesions."

This camera-scope, developed by Yaron's startup Visionsense, has since been used in thousands of operations globally. Yet he remains dissatisfied with the solution. Although lifestyle changes couldn't cure his tumour, he believes they could have prevented it happening in the first place. "Even though I've spent years inventing within western medicine, I think it's not enough," he told the audience. "My hope is for a new field of medicine that allows physicians to measure stress levels or sleep and warn us, just as they do for blood sugar today."

"Investors said to me, 'Even the best surgeons can't help, and you want *us* to invest in you? Hello?'"



THE SPEAKERS

Back row: **Mark Emil Hermansen** Misha Glenny **Claudio Sassaki** Chad Robertson **Reeps One** Flo Morrissey **Christopher Pierce** Francis Bitonti **Niven R Narain** Carlo Ratti **Middle row:** Arthur Kay **Josh Tetrick** Frank Pearl **Jose Miguel Sokoloff** Christopher Matthews **Elizabeth Stokoe** Hyeonseo Lee **Sophie Scott** Avi Yaron **Andras Forgacs** Ryan Weed **Dror Sharon** Helen Keen **Front row:** **Antoine Blondeau** Martha Lane Fox **Freeman Osonuga** Gabrielle Aplin **Lars Williams** Paul Dolan



WIRED2015

Back row: Daniele Quercia **Brian Message** Stephane Kurgan **Arielle Johnson** Vincent Connaré **Annette Mees** Laura Kriefman **Eyal Gever** Izzy Bizu **Jacob Whitesides** **Middle row:** Denzyl Feigelson **Alison Killing** Meg Schwamb **Daniel McDuff** Alex "Sandy" Pentland **Caleb Harper** Nadezhda Tolokonnikova **Max Roser** Gillian Tett **Hiroshi Ishii** **Front row:** Arunima Sinha **Gabor Forgacs** Alisée de Tonnac **Lining Yao** Billie Black **Fredrika Gullfot**

WIRED INNOVATION & WIRED/THE SPACE CREATIVE FELLOWS

Francis Bitonti
Francis Bitonti Studios

Alisée de Tonnac
Seedstars World

Fredrika Gullfot
Simris

Arthur Kay
bio-bean

Helen Keen
Comedian and writer

Alison Killing
Killing Architects

Laura Kriefman
Guerilla Dance Project

Daniel McDuff
Affectiva

Annette Mees
The Human Project

Freeman Osonuga
Frontline Ebola doctor

Claudio Sassaki
Geekie

Meg Schwamb
Planetary scientist

Arunima Sinha
Amputee mountain climber
(INK Fellow)

Elizabeth Stokoe
Professor of social interaction

Ryan Weed
Positron Dynamics

Lining Yao
MIT Tangible Media Group

Antoine Blondeau

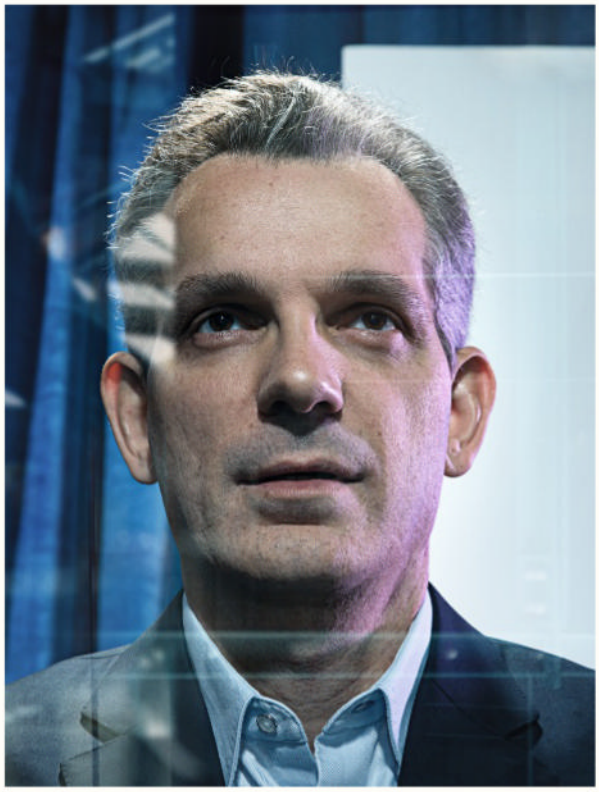
AI pioneer and CEO of Sentient Technologies

Sentient Technologies has assembled one of the world's largest artificial-intelligence networks, with two million CPU cores and 5,000 GPU cards. And Antoine Blondeau, the company's co-founder and CEO, wants to use this enormous image-processing power to sell you the perfect pair of brogues. "A picture is worth a thousand words," he explained to the audience. "You cannot Google for a specific shoe style or the perfect little black dress."

Sentient Technologies' partnership with online retailer shoes.com will be its system's first interaction with everyday consumers. But a shoe recommendation engine, no matter how sophisticated, is not the reason Sentient Technologies is the world's most-funded AI startup. "No one has ever scaled AI to this level before," said Blondeau, who previously worked on the technology behind Apple's Siri. "And networked intelligence is infinitely scalable. Such a system could take on huge problems."

These problems include the treatment of sepsis, a blood infection that affects a million intensive-care unit patients in the US every year, with a mortality rate of 20 to 50 per cent. "We asked practitioners, 'What do you need to fight this?'" Blondeau said. "They replied that if we could give them a 30-minute warning that sepsis is coming, they would be able to treat it." After collecting a year's worth of data on the arterial blood pressure of 6,000 patients, Sentient Technologies used its AI to create a system that, through continuous monitoring, can predict the onset of sepsis 30 minutes ahead of time with 91 per cent accuracy.

The company is now working alongside the University of Oxford on the genomics side of big data in healthcare. "This is just first base," Blondeau concluded. "This is day one of AI. We've only just begun."



"The search base is enormous. It would take eight years to traverse one per cent of the search base using a billion computers."



Arunima Sinha

The first female amputee to climb Everest

At one o'clock in the morning on April 11, 2011, Arunima Sinha – a former national volleyball player for India – was attacked by thieves and thrown from her Delhi-bound train. Laying on the tracks, she was hit by a second train that crushed her left leg. "I grabbed two rocks in my hands and I counted till the train was gone," she said. "I saw 49 carriages pass by my eyes." Seven hours later Sinha was rescued by villagers and taken to hospital where her leg was amputated without anaesthesia. As she lay recovering she was accused in the media of attempting to take her own life.

It would have been easy to give in. Instead, Sinha resolved to do the opposite. "I could not fight the system directly," she said. "But I thought to myself, 'Today is their day, but my day will come – I will prove who I am.' I decided to take on something. I was going to climb Everest."

So began two years of rigorous training at the Nehru Institute of Mountaineering: "No breaks. No Sundays. No festivals," she said. "My stump was raw and bleeding. But I kept working, because my goal is my life."

At 10:55 on the morning of May 21, 2013, after 52 days of climbing, Sinha reached the summit of Everest, becoming the first female amputee to do so. Now she is raising money to set up a free sports academy for the poor and disabled. "I thought, 'If I can do this, how can I help others in the same situation? How can I create many more Arunimas?"

THE INTERACTIVE ZONE

WIRED 2015

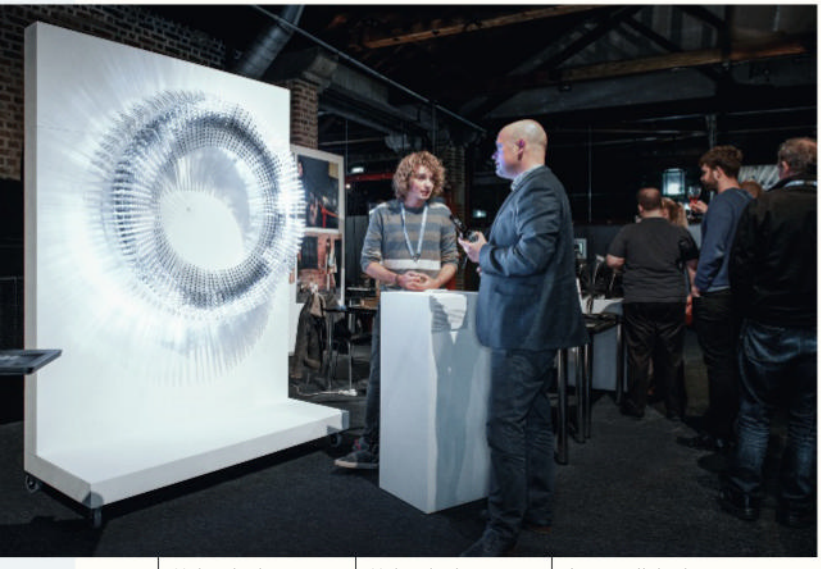
BY JEREMY WHITE

PHOTOGRAPHY: CHARLIE SURBEY

Many thanks also to our partners: Alchemy VR, Anki, Apple, Autodesk, BMW, Can-Am, Ducati, DxO ONE, Extreme Fliers, FirstvIsion, FOVE, GiveVision, HTC, ICAROS, MakerClub, Mogees, Moog, Naim Audio, Nerf, Philharmonia Orchestra, Polaris, Recon Instruments, Roli, SCEE, Salterns Brokerage, Smartdrone, Technology Will Save Us, Thalmic Labs, Visualise, VRSE, Williams and WizDish



One of the stars of WIRED2014's Test Lab was Mattro's off-road armchair, Der Ziesel. This year the company was back with its new drivable platform, the Bock. With two electric motors mounted between caterpillar tracks, it has mounting points on the chassis to allow for individual setups and configurations. Self-analysing double-redundant electronics and safety brakes, meanwhile, ensure you're in control at all times.



Haberdashery London's DiscoDisco modular lighting system is a collaborative project between Alex Asseily, design studio Goodwin Hartshorn and Haberdashery London and was inspired by the 70s disco ball. This modern version is brought up to date with sound-responsive capability and the sensitivity to react to everything from a clicked finger through to club-level music. Each acrylic fin is arranged on a simple spine, so the system can be expanded to fit a variety of spaces.

Each year at WIRED's flagship event we pull together not only the best technology from around the globe, but also glimpse into the future. For WIRED2015's Test Lab with Telefónica Open Future, the choice for the main theme was simple: virtual reality. In 2016, the major players in hardware battling for VR supremacy will release their creations to the consumer market.

What better year then to ask all these companies to show off their best prototypes to the WIRED community? HTC, Sony, Fove, Samsung, Google and Oculus were all represented at various VR experience points, some with bespoke content created specifically for WIRED, including the world's first full-body motion-tracked virtual-reality game, created by Visualise.

Here are some highlights from the 2015 Test Lab with Telefónica Open Future. For the complete video tour, visit wired.co.uk/wired2015.

One of the more eye-catching VR demos at the event, Activetainment's ebove is a training concept that aims to combine exercise and gaming. Incorporating bike riding with immersive visuals, it provides an engaging, entertaining and realistic indoor exercise – and one that left the WIRED2015 delegates somewhat lost for words. The Bluetooth-enabled B\01 bike, complete with gyro front wheel, links to an Oculus Rift headset as the rider navigates mountain trails or street circuits in cities such as Venice. And with on-board Wi-Fi it is now possible to race friends online, too.



Jaguar brought along its jaw-dropping C-X75, which is also the baddie's choice of transport in new James Bond film, *Spectre*. The concept car was powered by four electric motors outputting 778hp, with a pair of micro gas turbines for recharging. The on-screen version is powered by a more conventional supercharged 550hp V8 – but it's just as beautiful.





Without question the best-looking VR headset coming to market, Project Morpheus, as it was known in development, has an OLED display, rather than LCD. So colour rendition is nothing short of striking. Performance includes an impressive 120fps on a 5.7-inch screen, which matters: higher frame rates equal less image judder, which means less chance of losing your lunch. Sony has also got the PlayStation VR's latency down from 0.04 seconds to 0.018, so any lag in the final version should be practically imperceptible.



Emer Hickey & Ciara Judge

Google Science Fair winners

Being 14 is no barrier to solving world hunger, Emer Hickey (*near right*) and Ciara Judge (*far right*) told the crowd at WIRED2015: Next Generation, our event for teenagers. And they should know: that's how old they were when they started a project that could potentially boost crop outputs by 50 per cent.

"I was gardening with my mum, pulled up some peas and we found ugly wart-like rooty things on them," Hickey explained. "Doing our research we found out that bacteria lived within these nodules." The girls ran some experiments in the Judge family's spare bedroom, which showed that if these naturally occurring bacteria – *Diazotroph* – are present, it accelerates the germination process of high-value crops such as barley and oats, potentially boosting output by up to 50 per cent. Now 16, Hickey, Judge and team-mate Sophie Healy-Thow have won a host of awards – including at the 2014 Google Science Fair – and were named by *TIME* as three of the world's most influential teenagers.

"We were listed alongside [Nobel Prize laureate] Malala Yousafzai," Hickey told the audience. "She's a really big role model for all those girls who are passionate about education."

The duo have launched a startup, Germinaid Innovation, to develop their work. Many adults told them they were wasting their time, they said. "We ignored those people. Any idea you had while eating your breakfast could take you anywhere – so just follow it." **SA**

Patrick Kane

Bionic prosthetics campaigner

The word "disabled" is no longer fit for purpose, says teenage prosthetics campaigner Patrick Kane. "Blind people seeing, athletes running without legs and paraplegic people learning to walk again sounds like make-believe," the British 16-year-old, who describes himself as a "bionic teenager", told the packed room. He pointed to 80-year-old Ray Flynn, the first person in the world to be fitted with a bionic eye; Richard Brown – who can run 100 metres in 10.75 seconds despite missing his right leg below the knee; and James Johnson, a paralysed war veteran who is walking again thanks to a powered exoskeleton. Kane sees himself as belonging to this new post-disability age.

Kane made headlines in 2010 when he was fitted with the i-limb hand and leg by Scottish firm Touch Bionics. He learned to walk on his first old-style artificial limb at just 17 months old, after a virulent bout of meningococcal septicaemia at the age of nine months left him with no leg below the right knee, fingers missing on his left hand and the fingers of his right hand irreparably damaged.

"I'm lucky I was born in London into a family who were able to afford the prosthesis I needed – however, not everyone is so lucky," said Kane. "The fact that the government is not willing to pay for advanced prosthesis such as mine is upsetting, because I truly believe that disability is curable." **SA**



NEXT WIRED GENERATION

OUR ONE-DAY EVENT FOR TEENAGERS

BY STEPHEN ARMSTRONG & OLIVER FRANKLIN-WALLIS

Mark McCaughrean

European Space Agency scientist

WIRED's teenage audience got a sneak peak at the science making us rethink how our planet formed and life in the Universe began, thanks to Professor Mark McCaughrean. A senior scientific adviser at the European Space Agency, McCaughrean worked on the Rosetta project, which successfully landed the Philae probe on comet 67P/Churyumov-Gerasimenko on November 12, 2014.

"Comets are the leftovers from the start of the solar system," McCaughrean explained. The unexpected discoveries of oxygen – alongside complex organic molecules – on 67P is at the end of the ten-year project, but just the start of the research. In September 2016, the agency plans to land Rosetta herself on the comet, in a bold finale to the groundbreaking space mission. "The adventure is not over," he concluded. **SA**

Bradley L Garrett

Social geographer

Trespassing is effectively a civic duty, said social geographer Bradley L Garrett from the Next Generation stage. "The moment we stop exploring our world, including the cities we live in, that's the moment they become dead," he told a slightly startled crowd.

An author and academic, Garrett (*below*) described urban exploration – researching and accessing off-limits spaces such as abandoned buildings, construction sites and tunnels – as the future of social geography. And, since trespassing is not a criminal offence in England, barring military facilities and railways, "Most of the city is fair game."

Garrett's footage – including some shot from the chimneys on Battersea Power Station – featured one urban explorer saying "place hacking" was like being a superhero. "If you want superpowers, here's your ticket," he added. **SA**

Jordan Casey

Serial entrepreneur

It's not quite the dawn of the *Club Penguin* generation, but 15-year-old Jordan Casey said that it was through learning cheats for massively multiplayer online games that he started his career in coding.

The Waterford-based entrepreneur has since topped the charts with games such as *Greenboy Touch* and *Alien Ball VS Humans*. He's now paying homage to *Club Penguin* with his own online virtual world *KidsCode*.

His biggest challenge? Maintaining a work/life balance. "I go to school, then work on my business [at night]," he says. "I need a break on the weekend to just hang around with my friends. That helps me keep going." SA

Thomas 'TomSka' Ridgewell

YouTube sensation

You suck, says social-media comedian TomSka. But that's OK. "Start off terrible, make a lot of terrible stuff – that's how you get there," he told the Next Generation audience. "You can't make something OK until you've made something that's bad." (His talk's title? Five Inspiring Things To Inspire You And Hopefully Make You Want To Do Stuff, or #5ittiyahmywtds.)

Ridgewell, who started out aged 11 by making animations in Microsoft PowerPoint ("That's how I thought it was done"), broke out with his animated short "asdfmovie" series. The first has now been viewed 50 million times, and Ridgewell's TomSka channel has 3.8 million subscribers. He has also written a comic-book, *Art Is Dead: the asdf book,* released this autumn. Ridgewell advised aspiring film-makers to look at every person in their lives as a potential collaborator and every location as a potential set: "I am a chef, the world is a kitchen, and everything inside it is an ingredient."

Ultimately, Ridgewell says, the proliferation of online content has been a democratising force – allowing anyone to be a film-maker. You just have to want it enough. "If you just follow the rules, you'll be fine," he told the Next Generation audience. "But you don't have to play by the rules." **OF-W**



"Look at the things you have: if one friend has a baby and another has a dog, and you've got a cameraphone – make a video: 'Baby fights dog!'"



Lauren Bowker

Materials alchemist

Clothing can now change colour according to the wearer's mood and reflect the conditions in the air, thanks to Lauren Bowker's London-based design startup THEUNSEEN.

Bowker, who describes herself as an alchemist, studied textiles before a long illness changed her perspective. "By the time I came out of hospital, I didn't want to create clothing for the catwalk anymore," she explained. "I studied chemistry to look at materials that could give you an early-warning system if you were going to get ill, or [monitor] how your spine or muscles are performing."

After a few years consulting for Formula One and aeroplane manufacturers, she launched THEUNSEEN, a collection of "weirdos that don't fit. We're called THEUNSEEN because we like to visualise stuff within the environment or the human body that your senses can't perceive."

Her work includes a jacket which changes colour according to pressure, UV light and moisture levels, and a Swarovski collaboration that led to a headpiece with modified crystals that act as a printed circuit. Most recently, Bowker has used a material that links to an EEG kit or smartphone, and can change colour according to whim. A capsule collection for Selfridges launched in October.

Bowker pointed out that nano surfaces were already routine in Marks & Spencer, and wearables were sneaking in under the radar. "Creating a garment that is going to benefit someone's life in some way is not about creating a fad," she concluded. "It's about creating something that gives the world a little bit more." SA

This is what school computing classes should be like, according to Tony Fish, co-founder of FabLab, the maker hub that powered the WIRED2015: Next Generation Maker Space. Standing in a room full of children, 3D printers, laser-cutters and robots, it's hard to disagree with his views on how exciting science and technology education could be. "Teachers have converted it into something dull, when it's supposed to be inspiring," said Fish.

Alongside a packed Main Stage schedule, teenagers attending Next Generation had the chance to go hands-on with the hardware and software that will shape their future.

NEXT WIRED GENERATION

THE MAKER SESSIONS

BY JAMES TEMPERTON

To help inspire students, computing classes should include everything from art to engineering – cornerstones of the maker movement. "What we're trying to do is turn kids from consumers to creators," said **FabLab**'s Tony Fish. With the help of a team of Next Generation volunteers, young innovators were able to design using 3D printers, go hands-on with laser cutters, make their own wearable technology and programme and control a robotic face. "It's a bit like [Iron Man] Tony Stark's lab," said fellow co-founder Ande Gregson.





With the help of Brighton-based technology education startup **MakerClub**, a group of 12- to 18-year-old children used coding tool Scratch to control robots they'd just built from servos, Plasticine, paper, sticky tape and paper clips. "They make mistakes and learn from them," said MakerClub founder and CEO Simon Riley.

"I love making robots," said Ikenna, 12. His father had already spotted his son's interest in computing and is keen for him to pursue it. But like most of the Next Generation attendees on the day, it was the chance to get hands-on and creative that enthused Ikenna.

By 2050, the world's population will pass nine billion. But how do we feed everyone? At Thought For Food's biohacking session (*below*), attendees were mashing raspberries, salt, sugar and soap into test tubes before adding isopropanol to isolate the DNA. In the future, home-brewed DNA sequencing could help farmers develop higher-yielding and more resilient crops. Or, as one excited attendee exclaimed, "I'm DNA man!"



Many thanks to **the Science Museum and Experimental Food Society Presents: The Robin Collective** for the additional workshops, and to our event headline partners Telefónica and Jaguar.

WATCH ALL THE WIRED2015 TALKS ONLINE

To view videos and highlights of WIRED2015, visit youtube.com/wireduk

PHOTOGRAPHY: CHARLIE SURBY



Left: **The AXA PPP Health Tech & You Awards 2016 was launched at WIRED2015**

Awarding innovation

Partner of two WIRED events, AXA PPP Health Tech & You is an award series designed to stimulate debate and growth in the health technology sector

Health technology is under-going a period of extreme evolution – which is why WIRED Health was launched in 2014 to showcase the pioneers in the sector. This year our two-day WIRED2015 event also welcomed healthcare innovators to the stage, with Niven R Narain showing how AI can help discover new drugs, and Avi Yaron explaining how he built a brain-imaging tool for use on his own tumour.

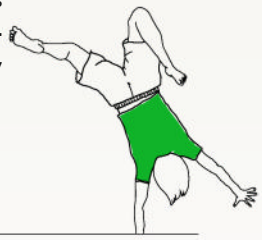
AXA PPP Health Tech & You was WIRED2015's health-tech partner and will support WIRED Health in April 2016.

"From organ bio-printing to artificial intelligence, we saw all aspects of technology take the stage at the conference," says James Freeston, marketing director at AXA PPP healthcare."It showed us all something new and helped to inspire the new generation of technology developers who attended the conference."

AXA PPP Health Tech & You aims to guide and grow the conversation about health tech, empowering people to use it to lead healthier lives and be more in control of their wellbeing.

Health-tech innovators, designers, developers and healthcare providers can enter the awards – now in its second year – before February 1, 2016. Finalists will be announced on March 1, and the ceremony is on April 25.

Enter now at healthtechandyou.com



THE SEVEN HEALTH TECH & YOU AWARDS CATEGORIES:

Breakout award
Focusing on finding a piece of health tech that's successfully embedded itself – and has made a difference to people's lives over the past year.

One to Watch award
Looking for tech innovations not yet in the spotlight, but with the potential to significantly impact people's lives in the future.

Champion award
Celebrating an individual or organisation who has most championed the uptake and adoption of health tech.

Problem/ Solution award
Offering the opportunity for those with an innovative concept or solution to a health need to further develop their concept, and bring it into the spotlight.

Health and Care award
Highlighting the consumer health-tech solution that has had the most positive impact for healthcare providers.

Innovator award
Looking for visionaries that have developed some of the most groundbreaking health-tech products or services in the past year.

Independent Living award
Looking for health-tech innovations or solutions that support quality of life management.

PHOTOGRAPHY: MICHAEL PALEODIMOS

Mapping the road ahead

JAGUAR INNOVATION

AT WIRED2015, JAGUAR EXPLORED HOW DESIGN AND TECHNOLOGY WILL EVOLVE IN THE NEAR FUTURE – THROUGH THE LENS OF ITS ALL-NEW XF

MATERIAL INNOVATION

The All-New XF lightweight aluminium architecture contains recycled alloy, which uses 95 per cent less energy to produce than primary aluminium. Light and efficient, the XF has CO_2 emissions as low as 104g/km.

EMOTIONAL CONNECTION

InControl Touch is XF's all-new 8-inch touch-screen multimedia system. The intuitive touch-and-swipe controls and voice input allow for full control over the car's audio, climate control and satellite navigation.



LOOKING AHEAD

To explore what makes the All-New XF such a fascinating car, WIRED and Jaguar joined forces to produce a series of films. Entitled *Out Of Office*, they see WIRED deputy editor Greg Williams (*pictured right, hosting panel*) on the road with some of the most interesting speakers from WIRED2015.

Fashion designer and technologist Francis Bitonti mused on the future of manufacturing, emotive-computer engineer Daniel McDuff explained how machines will soon better understand us, rocket scientist Ryan Weed discussed his vision for anti-matter propulsion, and Vincent Connaré talked about the human side of design. ***Visit wired.co.uk/newxf***

FRANCIS BITONTI

New York-based designer Bitonti blends digital design with new manufacturing technologies. His aim is to transform industrialised models of manufacturing and create new processes of distributed production.

DANIEL MCDUFF

Principal scientist at emotion analytics company Affectiva, McDuff is combining developments in sensor technologies and algorithmic analysis of facial expressions to help machines understand us better.

Inherently innovative

DEBATE AND DISCUSSION AT WIRED2015

POWER & EFFICIENCY

Ingenium is the future of Jaguar engines. The XF's lightweight, ultra-efficient 2.0 litre i4 diesel delivers up to 24.9kpl, and comes in 163PS and 180PS models. The 3.0 litre V6 supercharged petrol engine creates 380PS.

DESIGN & PERCEPTION

The XF is designed to look fast – even when stationary. Its shape takes cues from classic Jaguars, and the sporty and distinctive F-TYPE. The cabin wraps around the driver for a connected, engaged driving position.





DOES TECHNOLOGY MAKE US MORE OR LESS HUMAN?

On day one of WIRED2015, Jaguar and WIRED co-hosted a panel discussion entitled *Humanity in the Digital Age* to ask the question: does technology make us more or less human? Representatives from Jaguar and MIT Media Lab debated the subject, which covered topics as diverse as artificial intelligence and self-driving cars to new forms of user interfaces and the perception that many of us suffer from an over-reliance on modern technologies.

CAN ENGINEERS SOLVE PROBLEMS DESIGNERS CAN'T?

In the second Thought Leadership session – *Integrated Innovation* – WIRED's Greg Williams asked the panel "can engineers solve problems designers can't?" Key individuals from Jaguar's design and production teams spoke alongside emotive-computer engineer Daniel McDuff and regular WIRED contributor and art curator Lucy Johnston. But did they reach a conclusion to this tough question? Watch the film online to find out.

THE PANELS

Chair: **Greg Williams**, deputy editor, WIRED.
Day one: **Alister Whelan**, creative director, Jaguar Interiors; **Peter Virk**, Jaguar's head of connected technologies and apps; **Avi Yaron**, medical-device builder; **Hiroshi Ishii**, tangible-interface designer; **Jerome B Wiesner**, professor of media arts and sciences, MIT Media Lab.
Day two: **Adam Hatton**, creative exterior designer, Jaguar; **Kevin Stride**, vehicle line director, Jaguar; **Daniel McDuff**, emotive-computer engineer; **Lucy Johnstone**, editor, Neon Birdcage.

WATCH THE OUT OF OFFICE VIDEO SERIES AT
WIRED.CO.UK/NEWXF

RYAN WEED

Pilot and physicist Ryan Weed is working to develop the world's first antimatter rocket – a propulsion system that can theoretically result in speeds of up to 115,000,000kph. Weed aims to make humans an interstellar species.

VINCENT CONNARE

Type designer Connare created the Comic Sans typeface at Microsoft in the 90s. It might have its detractors, but the font was styled to be a friendly, softer and more human typeface in the early days of personal computing.

Francis Bitonti | Daniel McDuff | Ryan Weed | Vincent Connare

PHOTOGRAPHY: MICHAEL PALEODIMOS

Join the high flyers

The sky's the limit if your company signs up to On Business, the new company loyalty programme from British Airways, Iberia and American Airlines

What do all successful businesses have in common? It might be that they all watch their overheads – especially those that do fly overhead.

By joining the new On Business company loyalty programme, SMEs can get more value from their travel budgets by earning points when their employees fly. Members also have access to member-only discounts and can spend On Business points on reward flights and upgrades.

On Business members earn points for the company, and individuals collect personal Avios if they're a member of British Airways' Executive Club. Points can be earned through British Airways, American Airlines and Iberia – as well as with British Airways American Express Corporate Cards* – to put towards future flights or upgrades. Seven thousand points can be redeemed against an economy reward flight to New York from Heathrow.

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So ask yourself, isn't it time your business took off? ***ba.com/onbusiness***

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Manage your flights, book tickets and check in online – using the BA smartphone and Apple Watch apps.



*Applies to UK only

IDEAS BANK

RHODRI JEFFREYS-JONES

State surveillance is more ethical than private-sector intrusions

The post-2013 attacks on state surveillance occasioned by the Edward Snowden revelations have been inappropriate in three ways: they have exaggerated the harm that state surveillance currently inflicts on civil liberties; they have offered few solutions to the security-versus-privacy dilemma; and they have ignored the actual harm imposed by private surveillance.

Yes, the tools for harming privacy are becoming ever more powerful. Snowden argued that the *1984* scenario has become an understatement. To him, George Orwell's "technologies now seem unimaginative and quaint. They talked about things like microphones implanted in bushes and cameras in TVs that look back on us." It's true – although Orwell gave us Big Brother and the rest of the vocabulary by which we describe the surveillance state, the means for effective surveillance have exploded since his book appeared in 1949.

Yet, equipped with these tools of oppression, political leaders in western democracies have shown more restraint than some of their precursors. In the past, successive presidents allowed the FBI to keep political dissidents and gay people under surveillance and to harass them. The UK government was complicit in a political purge of the BBC in the 50s and 60s. Such abuses of power are not occurring today.



Rhodri Jeffreys-Jones is the author of *In Spies We Trust: The Story of Western Intelligence* (OUP)

Those who criticise the NSA and GCHQ have failed not only to assess the actual harm those agencies cause, but have also not redressed a difficult policy issue. The proposal by the UK government for an investigatory powers Act attempts to address that issue. Wanting to curb organised crime and terrorism, home secretary Theresa May is attracted to the idea that the law should proscribe encrypted messaging, for example on *Snapchat*, Apple iMessage and *WhatsApp*. This is problematic because such a ban on encryption would leave online banking high and dry. Putting a blockade on imported encryption devices would mean filtering all internet traffic entering the UK. But what is the solution? Like Karl Marx, Orwell and Snowden have offered a critique of our world without supplying any answers.

Today's antistatist critics have, like Orwell, neglected the harmful effects of private surveillance. Private surveillance can be beneficial, as in the case of businesses that investigate other businesses to assess their creditworthiness – market forces cannot operate properly without informed trust. But private surveillance has a darker side to it as well.

To give two well-known examples, there's the "market research" that lies behind the cold call, the pop-up ad and the inexplicably declined mortgage application. Once you place millions under apparently benevolent surveillance – for example, by compiling an



electoral register – it is all too tempting for public officials to sell on the information to private concerns. A second and high-profile example, in the UK, is the unrepentantly intrusive behaviour, notably phone hacking, by sections of the privately owned newspaper industry.

Less well known are the practices of private-detective agencies. "Divorce work" has been a staple source of income for them but to an even greater extent, especially in the US, they have engaged in "labour work", spying on workers to ensure they don't join unions or complain about safety. Worker surveillance is now commonplace. Specialist firms have come into being with the specific object of blacklisting "troublemakers". Perfectly respectable people – working on oil rigs, on bridge construction – lose their jobs and are prevented from working again. The damage is measured in terms of divorce, suicide and depression. There's the harm and it's not just potential – it occurs daily.

Edward Snowden's revelations triggered a debate that usefully illustrated the extent and potential danger of state surveillance. But his timing and his aim were poor. Today's harm comes from private, not state surveillance.

ILLUSTRATION: TIM LAHAN

JAY SAMIT

Driving a car must be made illegal now



Driving a car will be illegal by 2030. Our economy will be severely impacted as millions of lorry drivers, cabbies and delivery people are put out of work. In this era of endless innovation, humanity's century-long relationship with the automobile is about to be permanently disrupted. The reason has nothing to do with millennials, *Uber* or improvements in mass transport. Driving should and will be made illegal because we now have the technology to prevent deadly traffic accidents, one of the greatest causes of premature deaths.

More than 1.2 million people are killed in car accidents each year. Last year, more than 275,000 Chinese, 238,000 Indians and 36,000 Americans died in preventable traffic accidents. Since Ralph Nader first took on the car industry by publishing *Unsafe at Any Speed* in 1965, automobile manufacturers have radically improved the safety and reliability of their vehicles. Seatbelts, airbags, anti-lock brakes, as well as tyre-pressure-monitoring, have all reduced traffic deaths. But, until now, makers were unable to deal with the single biggest cause of fatalities: human error. We now have the technology to save millions of lives, but does society have the willpower to mandate its use?

Google's autonomous vehicles have logged 1.5 million kilometres on roads dominated by human-driven cars. Subjected to the same real-world conditions as us mere mortals, self-driving cars have been through rain, sleet and snow. These vehicles have driven the equivalent of circumnavigating the globe 40 times, without incident. In July, Google reported 14 minor road accidents in total – but in all of the cases blamed human error.



Jay Samit is a serial entrepreneur and author of the book *Disrupt Yourself* (Bluebird)

According to the data, human-driver error is responsible for 94 per cent of all crashes. And regardless of the amount of education or training, human behaviour behind the wheel is not improving. Alcohol is responsible for a third of all traffic-related deaths worldwide. In the US, one out of four accidents is caused by texting and driving (six times likelier to cause an accident than driving drunk). The more technology we put in human hands, the worse our driving becomes. And, unlike robots, humans need rest.

Autonomous vehicles don't drive drunk, don't drive distracted and don't fall asleep at the wheel. Self-driving cars are wired with cameras, infrared sensors, networked maps and a host of software that empower them to avoid dangers accurately in ways humans cannot. They can brake faster, swerve more quickly and anticipate changes in road conditions that are imperceptible to the human eye (such as obstacles beyond the range of headlights). Robots are also able to communicate with one another more efficiently and effectively than do we humans. Imagine *Waze* for robotic vehicles: software guiding millions of drivers at optimal speeds, reducing congestion, shortening commutes and eliminating the need for costly public road-expansion projects.

Elon Musk said: "People may outlaw driving cars because it's too dangerous." With two billion vehicles on the roads, a full transition to autonomous vehicles will take two decades. But, according to the Eno Center for Transportation, even partial penetration will save 21,000 lives a year in the US alone. We should work on making human driving illegal by 2030 as if our lives depended on it, because 18 million people's lives actually do.

PEDRO DOMINGOS

The race for the master algorithm has begun

Geoff Hinton believes that the way our brains learn can be captured in a single algorithm, and he's spent the last 40 years trying to discover it. A psychologist turned computer scientist who now splits his time between Google and the University of Toronto, he tells of coming home from work one day in a state of great excitement, exclaiming, "I did it! I've figured out how the brain works!" His daughter replied, "Oh Dad, not again!" But after many ups and downs, his quest is starting to pay off. Backpropagation, a brain-inspired learning algorithm that he co-invented, is taking the world by storm. Rebranded as "deep learning", it's used by Google, Facebook, Microsoft and Baidu for, among other things, understanding images and speech as well as choosing search results and ads to show you. DeepMind, the startup that Google paid £400 million for, is essentially a backpropagation shop.

Hinton is the leader of the connectionists, a school of thought in machine learning that takes its name from the belief that all our knowledge is encoded in the connections between neurons. The most optimistic of the

ILLUSTRATION: DAVIDE BONAZZI; LEANDRO LIMA



connectionists think backpropagation is the "master algorithm": a single algorithm capable of learning anything from data, and therefore of ultimately automating all knowledge discovery. But the more sober ones admit that backprop is still a far cry from the master algorithm, and other machine-learning camps have very different ideas on how to get there.

Take the evolutionaries. Led by the University of Michigan's John Holland until his death in August 2015, they believe that evolution, not the brain, is the master algorithm. Backpropagation may be good for fine-tuning connections between neurons, but evolution created all life on Earth. In the 60s, Holland started simulating evolution on a computer, complete with populations of competing individuals, fitness scores and sexual reproduction between the fittest individuals. By the mid 90s, his followers had succeeded in evolving devices such as radio receivers and amplifiers from random piles of components, amassing an impressive collection of patents along the way. Now they're busy evolving real hardware robots, with the fittest individuals in each generation programming 3D printers to produce the next one. If the T-1000 from *Terminator 2* ever comes to pass, this may well be how it happens.



Pedro Domingos is a computer scientist and author of *The Master Algorithm: How the Quest for the Ultimate Learning Machine Will Remake Our World* (Allen Lane)

But most machine-learning researchers believe that imitating biology, whether it's evolution or the brain, is at best a very circuitous path to the master algorithm. Better to solve the problem from first principles, using what we know from computer science, logic and statistics. For Bayesians, creating the master algorithm boils down to efficiently implementing Bayes's theorem, a mathematical rule for updating our degree of belief in a hypothesis when we see new evidence. A long-persecuted but now-ascendant minority in statistics, Bayesians maintain that if a learning algorithm is not consistent with Bayes's theorem, it must be wrong. But learning with hypotheses rich enough to put in a robot's brain was beyond their power until Judea Pearl, a professor at the University of California, Los Angeles, made a breakthrough for which he won the Turing Award, the Nobel Prize of computer science, in 2011. Pearl's Bayesian networks, as they're called, can encode probability distributions over millions of variables without breaking a sweat. Your first self-driving car will probably have one inside.

Bayesian networks are still not powerful enough for the symbolists, the machine-learning camp closest to classic, knowledge-based AI. Symbolists such as Imperial College's Stephen Muggleton believe a truly general-purpose learning algorithm must be able to freely combine rules, and they discover those rules by filling the gaps in deductive reasoning: if I know that Socrates is human, what do I need to know to infer that he's mortal? That humans are mortal, of course – and now we can add this newly discovered rule to our knowledge base. Eve, a robot scientist at the University of Manchester, works on this principle. Starting with basic knowledge of molecular biology, she formulates hypotheses, runs lab experiments to test them, and repeats, all without human help. In 2014, Eve discovered a new malaria drug.

Where symbolists' algorithms emulate the thought processes of scientists, those of the analogisers, the fifth and last major machine-learning tribe, are more like a lazy child that doesn't study for an exam and then improvises the answers. Faced with a patient to diagnose, analogy-based algorithms find a patient in their files with the most similar symptoms and assume the same diagnosis. This may seem naive, but analogisers have a mathematical proof that it can learn anything given enough data. That could be a lot of data, though, so they're working on more sophisticated forms of analogical reasoning to go the rest of the way. Douglas Hofstadter, cognitive scientist and author of *Gödel, Escher, Bach*, has no doubt that analogy is the master algorithm.

Who will win the race to invent the ultimate learning algorithm? Perhaps none of the five major camps has all the pieces of the puzzle, and what it will take is a combination of ideas from them all: a grand unified theory of machine learning, akin to the standard model of physics or the central dogma of biology. Or perhaps it will take entirely new insight, which may come not from a professional researcher but from an outsider or a student in a dorm, like Geoff Hinton was when he started out on his quest.

KATHLEEN RICHARDSON

We need an adult debate about exploiting sex robots

Imagine a world where you were the centre of the universe! Where only your thoughts and feelings mattered! You could have the type of sex you wanted with another human being without any consideration of their subjectivity! You could in fact turn off your "human switch"! Does this world sound like a nightmare to you or a state of bliss? Well, you can already do this. You can do this if you buy sex. The technological utopians are now offering you more of this – you can do it with a robot.

What are these connections between prostitution and sex robots? In David Levy's book *Love and Sex with Robots*, he proposes that relations between prostitutes and clients show a sexual relation where no empathy is present. This, he believes, is what can be transferred to sex robots, stating the "parallels between paying human prostitutes and purchasing robot sex". His book doesn't draw on consenting adult relationships for a future of sex and love with robots. He draws on prostitution as the model for his "utopia". A world that revolves around the buyer with no attention paid to the other.

Levy along with others is trying to make sex-and-love robots a more mainstream area of academic research. In November 2015, the Second International Conference on Love and Sex with Robots was held in Malaysia. This is a country with an estimated 150,000 prostitutes – although prostitution is officially illegal – and is also notorious for human trafficking for forced labour as well as sex. The buying of sex doesn't just affect adults. According to the Child Rights International Network, the "child-sex industry is a lucrative market as clients pay double the amount paid to an adult". European men flock to Asia to buy the kind of sex they want, where fewer political regulations and more economic poverty exists.

Some say prostitution is really "sex work". By being called sex work, the selling and buying of sex can be fitted neatly into the consumer market, along with waitressing, banking and the educational and medical professions. After all, we're all selling our labour, right? However, let's think about this for a moment. There is no profession in the service sector where you're allowed to enter another human body for your own pleasure. In fact, medical professionals are given special rights of access over another human body, and can act only from the perspective of the patient. Medical professionals operate according to the Hippocratic Oath, outlining good ethical practice:





Kathleen Richardson is a senior research fellow in the ethics of robotics at De Montfort University

"I will remember that I remain a member of society, with special obligations to all my fellow human beings, those sound of mind and body as well as the infirm." If the medic stops doing this, it's called sadism and malpractice.

We live in a culture where people freak out if you come too close. Sex with another person, by virtue of its nature, is always intimate. The personal space threshold is crossed. But the person inside the body is not fully recognised by the buyer of sex. This is shown time and time again in interviews with men who buy sex. They say, "Look, men pay for women because he can have whatever and whoever he wants" or "I feel sorry for these girls, but this is what I want".

We humans possess this wonderful quality: empathy. Autism expert Simon Baron-Cohen has called it the "glue of the social world, drawing us to help others and stopping us from hurting others". What happens in a prostitution-client encounter is you are allowed to "switch off" your empathy for another person. Supporting prostitution is encouraging people to stop being human. Do we want to encourage more of this by extending this lack of empathy to robots?

In June, I spoke at the Science Museum about the Campaign Against Sex Robots and Prostitution. It's focused on raising awareness in the robotics community about the ways gender, sex and race are imported into the design of robots. I'm all for developing robots but not if they further harm human beings.

ILLUSTRATION: MAX-O-MATIC



Space-aged Scotch

At WIRED2015 Ardbeg unveiled the future of whisky with its zero-gravity enhanced malt and the new Haar carafe

One of the clearest takeaways from WIRED2015 was that the ways in which we create and consume food and drink is changing. The single malt whisky from Ardbeg – which provided drams at the Test Lab Inspired by Telefónica Open Future after-party – is proof of that.

Guests were invited to set aside their assumptions about how to taste whisky with Ardbeg's Haar, a carafe that transforms whisky into a mist, using ultrasound technology. Rapid vibrations break the liquid down into a gas of micro droplets, which form a smoke-like cloud – an intensely olfactory way of sampling the Scotch.

The Ardbeg team isn't stopping there. WIRED2015 also showcased the distillery's collaboration with US space startup NanoRacks: whisky matured in space. Ardbeg sent its product 320km above Earth in a bid to understand the effects of zero gravity on its flavour. After travelling at 28,000kph for nearly three years, analysis by independent tasters and scientists suggests that the single malt's terpenes – the fundamentals of a whisky's flavour profile – were found to have been altered. The resulting smoky taste was beyond what Bill Lumsden, Ardbeg's head of distilling and whisky creation, had ever encountered.

By experimenting with its range, Ardbeg is proving that partnerships and new technologies can help push the boundaries of whisky-making and continue to evolve the industry.

For more information, see ardbeg.com

KNOW YOUR WHISKIES



Ardbeg is an Islay single-malt Scotch whisky that's renowned for being the smokiest single-malt around. It has been named World Whisky of the Year four times in the last six years.



TEN
A complex and peaty single malt, the ten-year-old is non-chill-filtered and strikes a balance between malty, natural sweetness and smoky, fruity flavours.



UIGEADAIL
Combining Ardbeg's characteristic smoky tones with sweet treacle and winter spices, the Uigeadail has raisin notes from ex-sherry casks and is a festive favourite.



CORRYVRECKAN
Named after a whirlpool near the Isle of Islay on Scotland's west coast, Ardbeg Corryvreckan has a mysterious aroma that's heavily peaty for such a well-balanced whisky.

PHOTOGRAPHY: CHARLIE SURBEY

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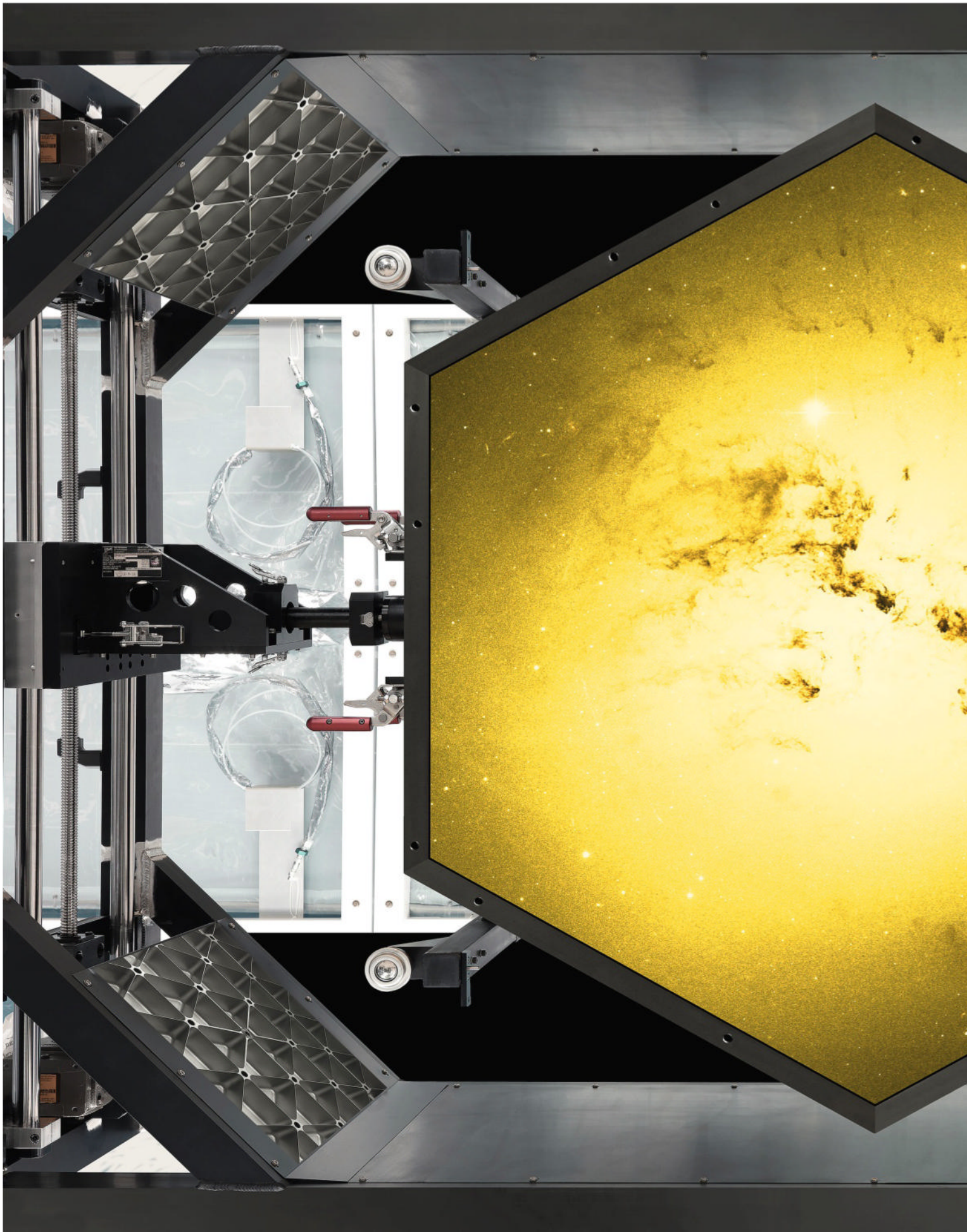
WIRED Energy

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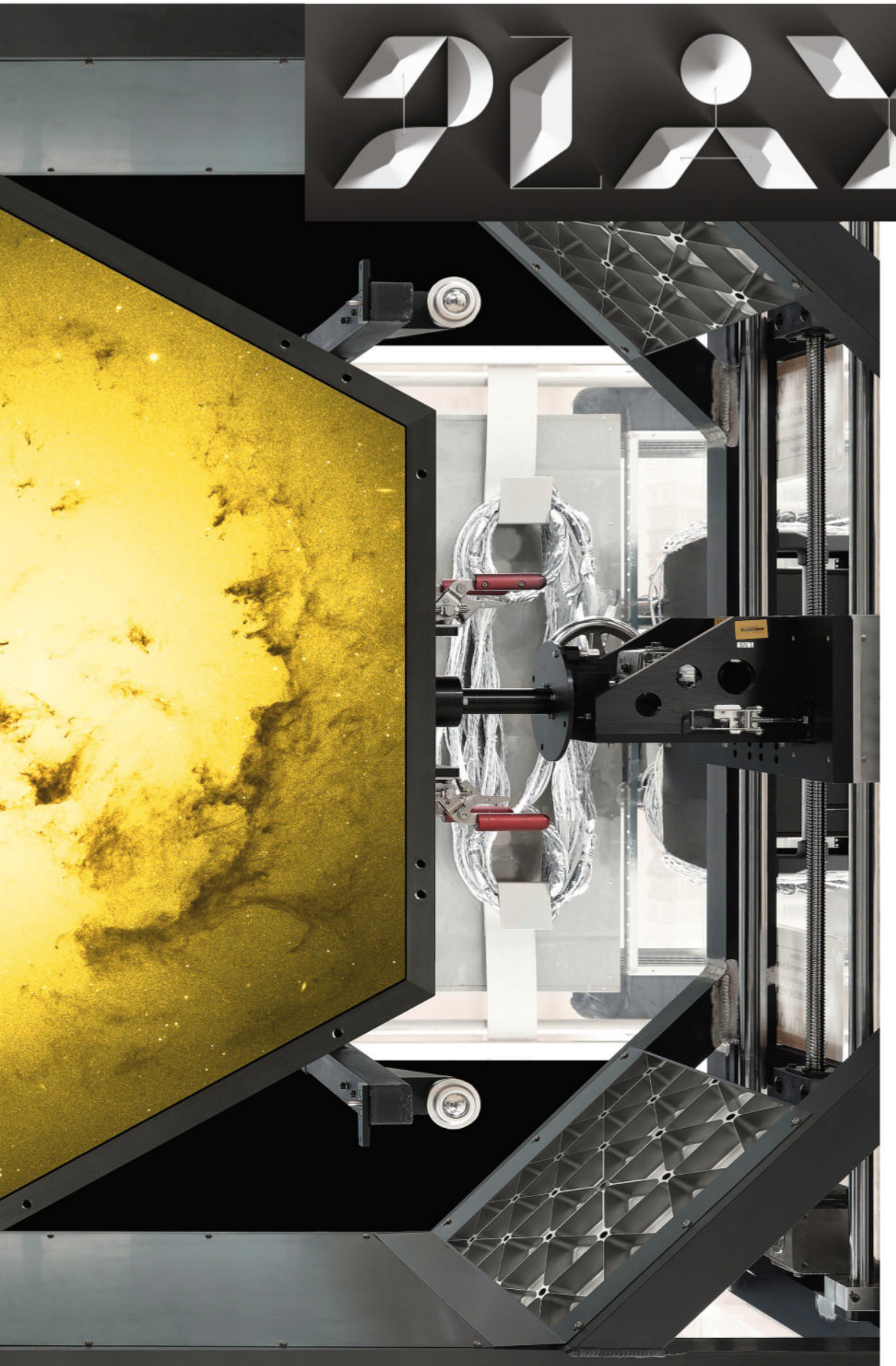
PLUG IN TO THE NEW WAVE OF POWER BROKERS



∨ *golden eye II*, 2012. One of the golden mirrors for the James Webb Space Telescope, which will launch in 2018. Najjar shot it using a digital Hasselblad. “I talk a lot to scientists to understand the ideas and projects they are working on.”



PLAY



ONE SMALL STEP, ONE GIANT CANVAS

Michael Najjar is on a mission: to be the first artist in space. "Space travel has been a lifelong fascination," says the German photographer, 49. "Now fiction has become reality."

Najjar's *outer space* series began when he was photographing the final shuttle launch, *Atlantis*, in 2011. "I realised that working on the topic of space travel meant flying into space myself," he says. With backing from three collectors, he bought a seat on Virgin Galactic's *SpaceShipTwo*, and has been photographing his preparation – including high-g training and a rare look inside Russia's Star City astronaut training facility. "It took a year to convince them," says Najjar.

The series will show at New York's Benrubi Gallery in March 2016, and is intended to culminate with Najjar's own space flight. *michael najjar.com* **OF-W >**



^ *gravitational rotator*, 2013. TSF-18, in Star City, Russia, is the world's largest astronaut training centrifuge. "[At high g-forces], the blood leaves your brain and you lose colour vision."

v *serious anomaly*, 2015. Najjar created this depiction of the October 2014 *SpaceShipTwo* wreckage by combining real crash imagery with Najjar's own footage of the craft, shot with a Hasselblad H4D.



^ *final mission*, 2011. This image of the space shuttle *Atlantis* launch at the Kennedy Space Center in Florida, on July 8, 2011, is the first in Najjar's *outer space* series. It's a composite of three different launch phases and is intended to show the huge energy required for lift off.


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Compiled by Cleo McGee





1 2
3 4





1/Master & Dynamic MH40 headphones

The MH40 headphones are finely tuned to provide a rich, warm sound – perfect for blocking out the world around you. Master & Dynamic claims these luxury headphones are built to last for decades. Shown in gunmetal and black, the over-ear cans come in a variety of finishes.
£319
masterdynamic.co.uk

2/Surefoot custom ski boots

Surefoot ski boots' insoles are custom-made by scanning the wearer's foot in 538 places. Surefoot takes this information and assesses the skier's skill level and usage to pick a suitable shell. Finally, the fit is finished using an injected liner – like slippers for skiing.
Price on application
surefoot.com

3/Thule Gauntlet 3.0 11-inch MacBook Air Envelope

This slimline, envelope-style laptop sleeve offers rugged protection without the bulk. Its tapered shape provides an exact fit for the 11-inch MacBook Air, and the semi-rigid EVA foam construction adds padded protection with extra corner and edge safety. Despite this, it weighs just 210g.
£39
thule.com

4/Laurent Ferrier For William & Son Galet Square watch

For those who like their timepieces exclusive, this 41mm, 18-carat rose gold limited edition is from a production run of five. Created for William & Son, this self-winding watch has a sapphire crystal blue dial and rose gold hour-markers to make it stand out from the crowd.
£37,800
williamandson.com

WIRED INSIDER'S PICK OF UPCOMING EVENTS

WIRED HEALTH

WIRED Health returns to London's 30 Euston Square in April 2016. Now in its third year, the event will look at the health sector through the lens of technology to unpick the developments and trends of the future. From diagnostics and neuroscience, to data-driven healthcare and new material sciences, WIRED Health will explore what's next for this critical sector.
April 29, 2016
wiredevent.co.uk

WIRED MONEY

WIRED Money returns to the British Museum in 2016 after a highly successful 2015 event. Now in its fourth year, the one-day summit studies the fintech sector at a time when banking and the financial world are evolving at a meteoric pace – thanks to a boom in apps, services and startups. Be there to meet the innovators changing the financial industry.
June 23, 2016
wiredevent.co.uk

MORE WIRED EVENTS

Our two-day flagship event returns in October 2016. In addition, WIRED Retail will also be held in November. And WIRED is launching two new conferences in 2016: WIRED Security and WIRED Energy, taking our conference count to seven. Keep an eye on wired.co.uk for details, dates and speakers – as well as information about the forthcoming sector-based startup stages.

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PHOTOGRAPHY: SUN LEE



PHOTOGRAPHY: DAVID VINTINER; GETTY

The AI says you look hot

Nothing to wear? Thread has 3.7 trillion style suggestions

Algorithms are already helping us to decide what to watch and listen to. But style is more complicated. "Fashion is a gnarly domain," says Kieran O'Neill (*above*), CEO and co-founder of London-based startup Thread. "For one, all of the things you're going to recommend often expire within weeks."

Thread employs eight human personal stylists, who perform an initial consultation with each new client on sign-up. Its machine-learning algorithm then trawls through more than 31 million customer-submitted ratings, along with 3.7 trillion possible item combinations (each piece is tagged, to identify its characteristics) to recommend outfits.

"Humans couldn't look through a million options to find the right thing," says O'Neill, 28. "But a computer can't look at your picture and understand what [clothes] would suit you."

O'Neill made his first startup exit at 19 and sold his previous venture, games studio Playfire, in 2012. He founded Thread the same year, he says, to help men who don't follow fashion to dress better. One of its first customers was Instagram co-founder Kevin Systrom; it now has 200,000, and in August secured an $8 million (£5.2m) funding round led by Balderton Capital and including DeepMind co-founders Demis Hassabis and Mustafa Suleyman.

So, how does the AI fare? WIRED decided it was time to refine its standard garb of slim-fit jeans, grey Chuck Taylors and flannel shirts. Thread's suggestion: slim-fit jeans, black Chuck Taylors and a white T-shirt. Hardly a style revolution – but O'Neill says that's intentional, so as not to scare off new users. "The recommendations need to change over time," he says. Dedicated followers, your lives just got easier. **James Temperton** *thread.com*

Kieran O'Neill in the Oliver Spencer shop in Shoreditch

Tarantino's biggest fan

The Hateful Eight (out January 8) returns cult director Quentin Tarantino to the old American west – but the setting isn't the only thing that's familiar. Tarantino has called upon some of his most frequent collaborators, from Samuel L Jackson (again) to Michael Madsen (again). WIRED crunched the numbers to find QT's most regular star. The answer? Himself. **OF-W**

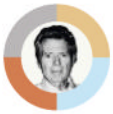
- Reservoir Dogs
- Pulp Fiction
- Jackie Brown
- Kill Bill: Vol 1
- Kill Bill: Vol 2
- Deathproof
- Inglourious Basterds
- Django Unchained
- The Hateful Eight



QUENTIN TARANTINO



SAMUEL L JACKSON



MICHAEL PARKS



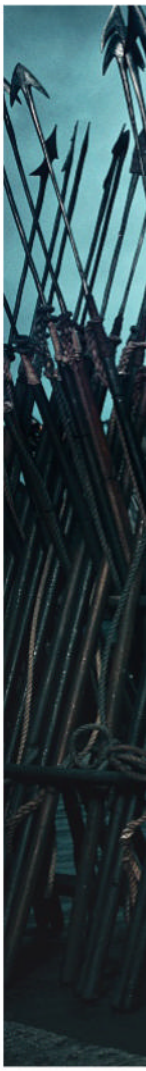
MICHAEL MADSEN



UMA THURMAN

Ron Howard and the whalers

The Oscar-winning director discusses the life aquatic on the set of his latest film



Ron Howard is obsessed with detail – whether he's tackling fire (*Backdraft*), space (*Apollo 13*) or Formula One racing (*Rush*). Now the Academy Award-winning director has ventured to the ocean for *In the Heart of the Sea*. It's a tale of adventure and unpleasantness: in 1820, the crew of the *Essex* sailed into the South Pacific to hunt whales, only to find themselves at the mercy of a 26m monster – the inspiration for Herman Melville's *Moby-Dick*. WIRED spoke to Howard about heading into the belly of the beast. Alex Godfrey **In The Heart of the Sea *is out in cinemas on December 25***

WIRED: *In the Heart of the Sea* is dark, but striking. The sequence in which the ship's crew are showered with whale blood is both disgusting and oddly beautiful.
Ron Howard: Well, part of the film is an awakening story, seen through Tom Holland's character [cabin boy Thomas Nickerson]. So it was important to keep touching base with his experience, what it felt like to be exposed to the awe of nature – the power, the danger and the beauty of it. And also I didn't want to shy away from the modern perspective that this is about the energy industry. This was how you got the oil. Commerce was driving a really brutal, destructive industry.

Did you have prior interest in seafaring?
Only for its inherent drama. The works of Herman Melville and Joseph Conrad. And that opportunity to see characters tested in this most primal and visceral – and therefore dramatic – way. I don't like the water much personally.

Nathaniel Philbrick, who wrote the book from which this film is adapted, said he looked to modern scientific studies to figure out what the *Essex* crew experienced. Did you delve into those areas too?
For the action moments, we took our inspiration from the journals of the *Essex*, from passages of *Moby-Dick* and from etchings and scrimshaw accounts of whale counter-attacks on whalers. We built pre-viz at [VFX company] Double Negative, then we shared them with marine biologists, who helped us refine the whale behaviour, so that it was entirely plausible. That was very important to me.

Did you have experts on location with you?
We had a guy named Steve Callaghan, who is a modern survivor: he was 76 days on the Atlantic Ocean, and wrote a book about it called *Adrift*. Over the last couple of decades he's studied survival at sea, he's written books, he's interviewed survivors. He was of tremendous value, not only because he could talk to us about starvation and survival, the emotional rollercoaster of that, but he also stayed on the movie and helped us as a sailor. He was out there on our whale boats. Then we had tall-ship sailors who came to work with us as our technical advisors. In terms of authenticity, I tried to set the same standards for this that I did for *Apollo 13*.

Did you join the cast at seamanship boot camp?
This movie came together quickly, it was very demanding, so I didn't have time to hang around and play – which I had done on *Apollo 13*; I'd gone to space school with the guys. I hadn't done much work on the water since the 80s, on *Splash* and *Cocoon*. There I developed the point of view that you could do a lot of work in the water if you went for an authentic, naturalistic approach and you didn't try to stage and align too many objects. If you could get a handheld camera on deck with the actors, you could accomplish a great deal. But if you started getting camera boats and helicopters, everything would get bogged down and start to feel artificial.

Below: director Ron Howard, on the set of *In the Heart of the Sea*, at Warner Bros' Leavesden water-tank facility



PHOTOGRAPHY: CHARLIE GRAY/AUGUST

How did you approach the CGI?
I was very pleasantly surprised to learn that not only does CGI allow us to create the whale in the most behaviourally correct, dynamic, revealing and surprising way, it also allows a director to actually be more ambitious about going on location and shooting in difficult places. Before, if you were shooting in the ocean and the light was right and the performance was great and the composition was what you wanted – but a barge appeared in the background – you were dead. The shot was ruined. Now those are easy fixes. It used to be so limiting that it pushed people to do more in tanks and on backlots. It was just so crushing.

'In terms of authenticity, I set the same standards for this as I did for Apollo 13'

You also shot some sequences in a water tank in Leavesden (a Warner Bros complex in Hertfordshire).
Three tanks: an outdoor, an indoor, plus underwater.

What was it like for the actors to shoot in tanks after getting the real deal on location?
We actually did it the other way round. Anything physically dangerous, requiring wires or stunts, destruction, fire, we shot in a tank. Then we went to sea and shot all the aftermath. The cast preferred the ocean. They could get off [the tank] and go to get some tea, but because we were doing all the difficult stuff it was really miserable – icy water dumped on them and being on hydraulics, getting tossed around.

The scene in which Nickerson goes into the dead whale's head to collect the oil: is that historically accurate?
Oh yes. That was one way in which it was done.

Tom Holland has said it felt like being in a real dead whale.
[*Laughs*] He gagged a couple of times, ha! That came to him very organically.

Did you go in there?
No – this is the beauty of being a director! I was standing at the monitor, chortling as Tom slithered down into the oil.



MAKING LIGHT OF TRAGEDY

Artist Janet Echelman creates otherworldly aerial sculptures. Composed of hand-spliced and knotted lightweight fibres, they're coloured by projected light. "They're about the complexity of interaction that we cannot predict," explains US-based Echelman, 49. "I am drawn to urban spaces, because I think that art should be part of life."

The pieces are designed using custom-made soft-body modelling software from Autodesk. It allows Echelman to model the interaction of every single element. She constructs the pieces from highly engineered fibres, such as ultra-high-molecular-weight polyethylene, which is 15 times stronger than steel.

Looms are used to make panels and then shapes are cut, knotted and spliced by hand. "My work is pre-industrial in terms of these old techniques. It's industrial with the looms. And it's post-industrial in terms of the digital analysis. We're not cut off from our past, but neither are we cut off from our future."

Echelman's latest will debut at the Lumiere London light festival in January. Its title, *1.8 London*, refers to the microseconds by which the day was shortened by the 2011 Japanese quake; the piece is inspired by a data set of the wave heights of the tsunami. Using smartphones, the public will be able to change the colour of the sculpture. "It's a contemplation on connectedness and the larger cycles of time," Echelman says.

Kevin Holmes

Lumiere London is January 14-17 visitlondon.com/lumiere

PHOTOGRAPHY: MELISSA HENRY. ILLUSTRATION: LAURINDO FELICIANO



Janet Echelman's *As If It Were Already Here,* which appeared in Boston, Massachusetts, in 2015

BRIGHT PLACE, BRIGHT TIME

What makes a city innovative? Location, location, location. In *The Geography of Genius* (Simon & Schuster), out January 5, Eric Weiner examines history's most creative locales. Here are three smart cities. GV



ANCIENT ATHENS

What made it great: Openness
"The willingness to borrow, steal and embellish distinguished Athens from its neighbours," writes Weiner. "Athenians were open to foreign ideas."



RENAISSANCE FLORENCE

What made it great: Rich investors
The city thrived under the wealthy Medicis, who invested in art and science – key factors in brewing revolutionary ideas. "Florence is about money and genius," says Weiner.



SILICON VALLEY

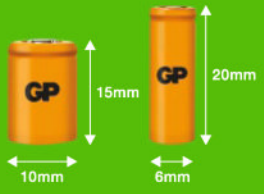
What made it great: First-starter advantage
Its success may just be about being the quickest at creating new tech, says Weiner. "First starters become magnets and, once magnetised, momentum takes hold."



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ILLUSTRATION: EERO LAMPINEN

APOCALYPSE POP

The second album from NZCA Lines mixes sci-fi and Moog

To listen to NZCA Lines – aka Michael Lovett – is like coming into contact with the monolith from *2001: A Space Odyssey* and falling into a musical black hole. "I've always been into science fiction," says the London-based musician, 28. "And I'm interested in making music that tells a story."

NZCA Lines's self-titled debut from 2012 took its cues from postmodern thinkers such as Italo Calvino and Jorge Luis Borges. Recorded in his bedroom, it earned rave reviews and comparisons with Cliff Martinez and Metronomy. But for new album *Infinite Summer* he took the sci-fi influences even further. "I was reading Asimov, Clifford Simak and Arthur C Clarke," he says. He constructed an entire narrative for the album, based around the future city of Cairo-Athens, set on a far-future Earth threatened by the collapsing Sun. He partnered with musicians Charlotte Hatherley (Ash/Bat For Lashes) and Sarah Jones (Hot Chip) to record a "wider, louder" sound – even if much of the album was still produced in the same bedroom. The result: an equal mix of sci-fi futures and Moog synths. Think *Interstellar* soundtracked by Daft Punk.

His track, "New Atmosphere", for example, is a love story about the hero falling for a terraforming scientist. For the video, which Lovett directed and produced, he created Cairo-Athenian architecture in design software SketchUp. He also created the effects, simulating blossoming clouds in a fish tank. ("You just inject double cream into water," he says.) This all helps to create music that asks deep questions in between beats. "When you know the world is going to be destroyed in 200 years, what do people do?" he laughs. "It's a funky apocalypse situation." **OF-W** Infinite Summer *is out on January 22 through Memphis Industries nzca-lines.com*

MUSICIANS TO LISTEN TO IN 2016

Want to know which artists to look out for in 2016? Here, the curators behind some of the UK's biggest music festivals pick their tips for your next playlist. Andy Morris



Oneohtrix Point Never
Recommended by Enric Palau, co-director, Sónar
"He's concerned with reinterpreting pop culture, not shunning it."
Key track: "I Bite Through It"



Declan McKenna
Recommended by Tom Baker, founder, Field Day
"With Logic Pro X and a Fender, he crafts gutsy guitar melodies. He is only 16 but his music is mature and anthemic, yet intimate and raw."
Key track: "Brazil"



Tiggs Da Author
Recommended by Jon McIldowie, booker, Community, and Reading and Leeds Festivals
"Tiggs Da Author is Tanzanian. There's really no one like him."
Key track: "Georgia"



Halsey
Recommended by Rob da Bank, co-founder, Bestival
"Halsey has a really engaging, fresh vocal, like a female The Weeknd. It's a majestic sound but also sultry and infectious."
Key track: "Ghost"

A boat that flies at 75kph

Hannah White is aiming for a sailing record – and for more women on water

When Hannah White heads out in her boat to train on Cambridgeshire's Grafham Water, she takes her life in her hands. *Speedbird*, the custom-made sailing craft in which she hopes to become the fastest female sailor over one nautical mile in March 2016, can travel at over 75kph. "If you move the tiller more than a millimetre, you can spin out of control," says the 32-year-old. Falling overboard at that velocity is like smashing into concrete.

A high-performance monohull, *Speedbird* raises itself out of the water on two T-shaped hydrofoils, reducing the area in contact with the water's surface. To optimise these supporting vanes, White and designer Dave Chisholm teamed up with Land Rover to tweak the design using CAD software and use a computational fluid dynamics simulation to assess the changes. New prototypes can be created overnight in carbon by a computer numerically controlled milling machine. "The current holder of the overall men's record took ten years," says White. "We were sailing our boat within 12 weeks of coming up with the idea."

White has already set a new record in her training boat (a commercially available vessel called a Moth) for crossing the Channel. She hopes such feats encourage those who lack a science background, as she does, to discover more about physics and also to inspire women to enter high-performance sailing. "Take [the 2015] Moth World Championships. There were probably 120 sailors – I think three were girls."

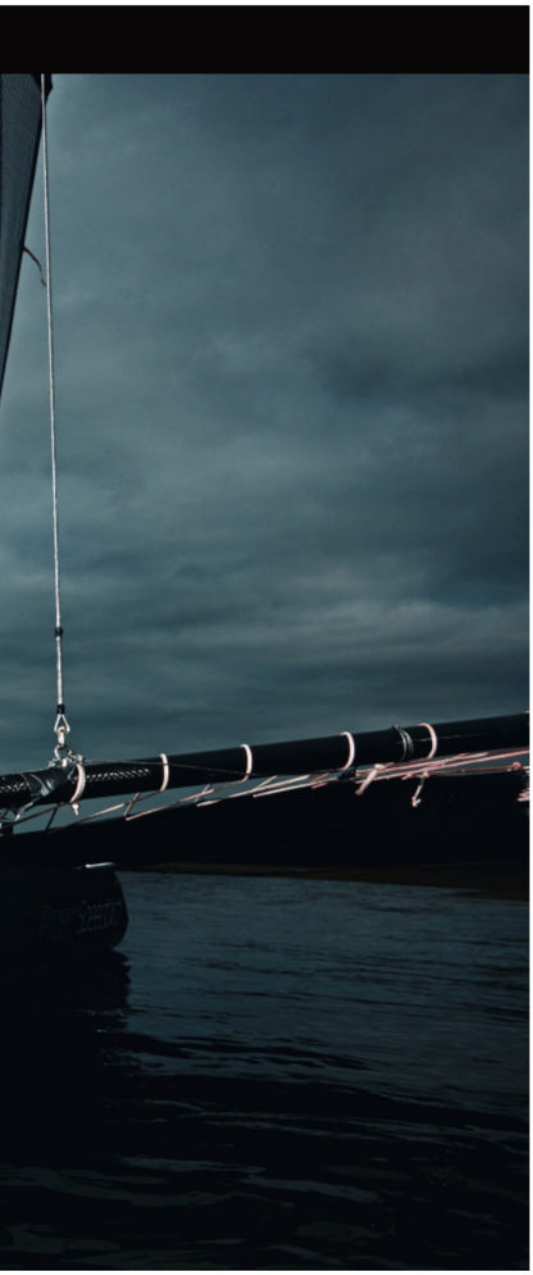
PHOTOGRAPHY: JAY BROOKS



Right: Hannah White and *Speedbird*. The boat is six metres long and its carbon-foil hull weighs eight kilos. Ahead of the attempt in March, White has already set a new record in her training boat



Her attempt coincides with other speed record attempts, including Bloodhound SSC [WIRED 12.14] and an AeroVelo bicycle [WIRED 2.15]. How does she explain this sudden trend? "Speed is very easy to understand – it spans such a range of disciplines and budgets," she says. "But it's ultimately about the same thing: A to B as quickly as you can." **Charlie Burton** *projectspeedbird.com*





Solving indie puzzles in pixel paradise

Players of developer Jonathan Blow's *The Witness* wander alone through a beautiful, deserted island. Explore, and you'll find panels depicting mazes. By solving these mazes – drawing a line between the start and end points – the player activates the panel. Some of these start machines or open up new areas; others reveal more about the story of the island. And that's pretty much it. There are no instructions, only more and more puzzles of developing complexity.

"I became very interested in the process of non-verbal communication and in developing a non-linguistic understanding of a situation," explains Blow. "What's exciting about games is that they can drop you into the actual thing, so you get experiential understanding."

Blow, 44, has become an influential spokesman for, and backer of, independent and experimental gaming since the runaway success of his 2009 platformer *Braid*. For *The Witness*, Blow's team at Thekla Inc – the San Francisco Bay Area studio founded to make the game – had to avoid repetition through around 650 panel-puzzles. They deliberately stripped down the interface, throwing out the item juggling and experimental clicking typical of adventure games.

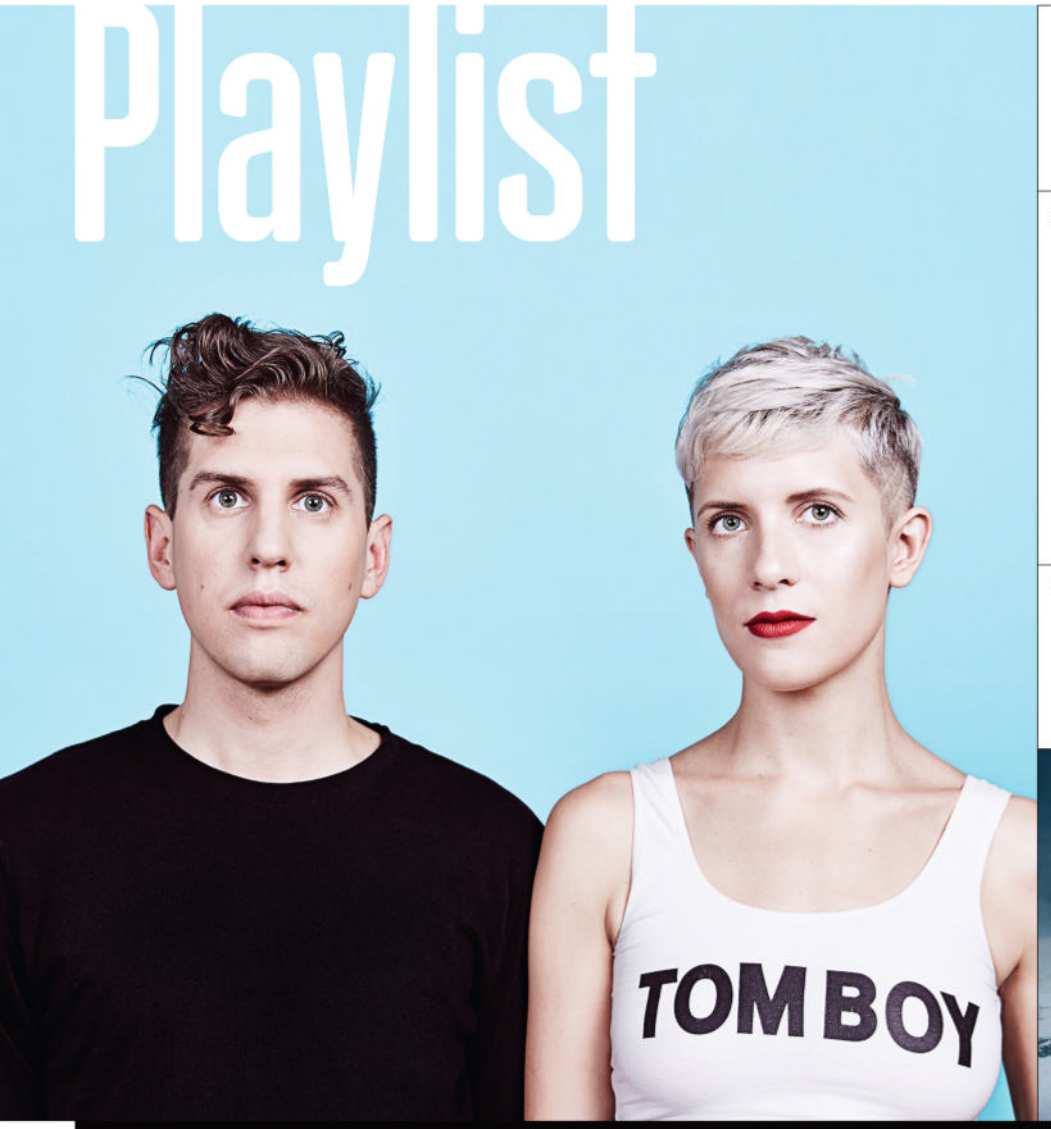
"There's a pattern that recurs a lot in this genre: a door that needs a key," says Blow. "But the keys in this game aren't physical – they are always in your head."

Although *The Witness* has grown in ambition and size since its inception, the heart is unchanged: "At the core of the game is the desire to look at this process all of us have, of trying to understand the world," he says. "And of wondering what our place is in it." **Daniel Nye Griffiths**

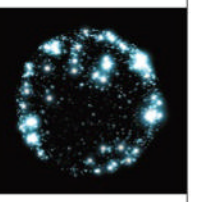
The Witness *will be available for PS4 from January 26*

Above: an example of a puzzle panel encountered in *The Witness*. Tracing the correct route affects the larger maze

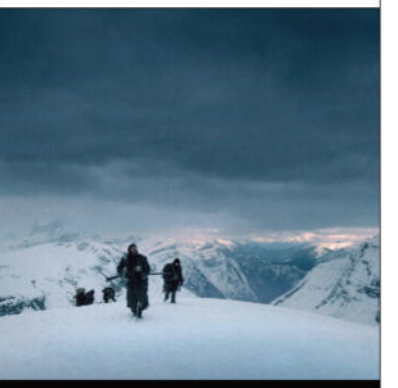
Playlist



▶THE ART OF DATA
Our data is valuable – but can it be art? Big Bang Data, a new exhibition at Somerset House in London, showcases our information at its most beautiful. *From December 3. bigbangdata.somersethouse.org.uk*



▼WINTER IS COMING
After the dazzling visual trickery of *Birdman*, director Alejandro González Iñárritu returns with *The Revenant*, a film already notorious for its groundbreaking cinematography and perilous shooting conditions. *Out Jan 15*



▼STACK-A-MOLE
Fabulous Beasts, a new board game from London design studio Sensible Objects, merges physical and digital play. Stack the real-world creatures to create hybrids in the iOS app – Jenga, meet CRISPR. *playfabulousbeasts.com*



▲FUTURE THINKING
Oregon duo YACHT – aka Jona Bechtolt and Claire L. Evans – have long played with tech themes, but new album *I Thought The Future Would Be Cooler*, is a future warning (drones) combined with retro-kitsch (an ode to fax machines). *teamyacht.com*



▲WHEN SCIENCE MEETS MAGIC
After winning a Hugo award for a short story in 2013, i09 editor Charlie Jane Anders makes her novel debut. *All the Birds in the Sky* combines magic and tech in a near-future San Francisco with dazzling prose. *Out January 26*



▲ODDS ON
Excelsior! Stan Lee is back in an unusual role: not creating a comic, but a new Sky 1 TV series. *Lucky Man* follows James Nesbitt as a very modern superhero. His power? To control luck itself. Chance would be a fine thing. *Starts January on Sky 1*

▶SNOOPY'S CHARTER
Fans of Charles Schulz's iconic *Peanuts*, which he drew for 50 years, get the chance to judge whether Blue Sky, the studio behind the *Ice Age* movies, has done Snoopy and friends justice. *Out December 21 peanutsmovie.com*



PHOTOGRAPHY: FRANCES MAIN; JOSHUA PORTWAY AND LISE AUTOGENA; ALLSTAR

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* BUT WITH FOOTNOTES. ILLUSTRATION: TONY RODRIGUEZ



Fig. 1 *Eisen awards his mock prizes to those who "oversell the microbiome"*

MICROBIOLOGY

The microbiome's gut defender

Can faecal transplants treat schizophrenia? Do probiotics cure asthma? Only in Jonathan Eisen's awards for fake science and hyped reporting. By Emma Bryce

LAST YEAR, A FLURRY OF MEDIA ARTICLES MADE A CONTROVERSIAL CLAIM: ORAL HYGIENE COULD DETERMINE a woman's risk of preterm birth. Journalists had widely misinterpreted a study by foetal-health experts at the Baylor College of Medicine, Texas, which showed that microbes in babies' guts matched those in their mothers' mouths. The study also correlated preterm birth risk with certain types of oral bacteria in women. Jonathan Eisen, an evolutionary biologist and science blogger based at the University of California, Davis, pounced on the media's misleading reports: the study made no causal link between mouth bacteria and preterm birth, he wrote on his blog, so it was ludicrous to imply that better oral hygiene averted problem pregnancies. Eisen slammed journalists from *The New York Times* and *Science*, plus the study's lead author, who'd fuelled the misinformation >

during interviews. Each received his mock "award" for "Overselling the Microbiome", which he routinely uses to alert readers to dubious science.

When he's not quashing the spread of misinformation, Eisen, 47, runs a lab at UC Davis's Genome Center where he studies microbes, the vast community of micro-organisms made up mostly of bacteria, viruses and fungi. He investigates how they co-evolve with their hosts and develop new functions. As the academic editor at open-access journal *PLOS Biology*, Eisen's also an outspoken advocate for accessible science. His research, together with his high-profile blog The Tree of Life – which receives millions of visitors – has placed him in the spotlight in recent years: he presented a talk at TEDMED 2012 called "Meet Your Microbes", giving the audience a primer on these pervasive micro-organisms.

Indeed, there are few places on Earth where microbes don't thrive; the human body is a microbial hub[1], packed with possibly trillions of microbial cells that interact with our own cells in myriad ways – many of which we're only just discovering. But as research on the human microbiome unfolds cautiously, microbe pseudoscience is on the rise, inspiring Eisen to take up his weapons.

In this case, the weapon is his writing. Via his blog (phylogenomics.blogspot.co.uk) he has risen to prominence as an authority unafraid to slam bad science, issuing his mock "awards" to make his point. "There are two ends to this. There's ridiculous stuff about why we should kill all microbes. That's the germophobia club," says Eisen. "And then there's 'microbiomania', those people who think microbes are beneficial and do everything."[2]

If you believe what's out there, the right balance of microbes could prevent strokes, melt away obesity and improve sex drive. And a mere sampling offers a fingerprint of your future disease risk. "It's endless how much BS is out there," Eisen says. "Literally, there are clinics advertising faecal transplants to cure schizophrenia. I have given them awards." In April 2014, Eisen debunked an article concerning faecal transplants which featured David Perlmutter, an American physician known for his holistic approach to treating brain disorders. Perlmutter claimed in the interview on Mercola.com that the transplants could prevent Alzheimer's by boosting gut flora – but Eisen swiftly panned the article, saying Perlmutter "should be ashamed for misleading people like this". In another instance, Eisen flattened a press release from Cedars-Sinai Medical Center in Los Angeles that made the outrageous claim that probiotics can remedy everything from asthma to irritable bowel syndrome by promoting good bacteria. "There are so many sites out there offering probiotics for sale it reminds me of Viagra," Eisen chirped on his blog. And, last year, he tackled *TIME* for insinuating that reduced antibiotic use allows the body's microbiome to become more effective at staving off cancer, among other things. Exasperated, Eisen wrote, "Do we really need to overstate what we know in order to effect change?"

Eisen's lab liaised with the public to find out whether microbes grew differently on the ISS

Since he launched his Misselling the Microbiome Award in August 2010, he's produced over 30 takedowns on his blog. The microbiome – overwhelming, complex, largely unknown – is ripe for misrepresentation. "One of the reasons I think it's a big deal to not oversell the microbiome, and the reason I blog about this relentlessly, is that it's really complicated," Eisen says. For instance, faecal transplants do seemingly transfer improved gut health to unhealthy people, and there is a potential link being investigated between microbial diversity and mental health. Yet in most cases, studies on microbes show observed correlations, not causal proof. According to Eisen, many aspects of our health are most likely affected by microbes, but "'most likely' isn't good enough for telling people how to medicate them" – at least not until the science advances.

Policing the microbiome is central to Eisen's identity, but when he's off duty, he prefers to improve it in a different way: by producing respectable research. Eisen isn't just a guardian of truth; he also aspires to be a "guardian of microbial diversity" according to his Twitter bio. Together with collaborators he's leading the largest microbe-sequencing project to date, based at the US Department of Energy Joint Genome Institute, California. With the accumulated data – thousands of microbes have already been sequenced – Eisen wants to build a vast microbe "tree of life", and with it, a companion "Field Guide to Microbes" intended as an open-access tool for identification.

This quest has delved into the microbial communities of rice, corn, seagrass, frogs, fish, cats and humans, using microbe DNA to identify species. "The field guide is not just about cataloguing organisms; it's not stamp collecting. When you find new things, this is how you place them in context," Eisen says. A major goal is to pinpoint organisms that have been co-evolving with their hosts: Eisen suspects these long-time partners provide benefits. "That's important because if it's true, we can use this approach to filter through the thousands on a particular organism, and find the ones that are most likely to be beneficial," Eisen says.

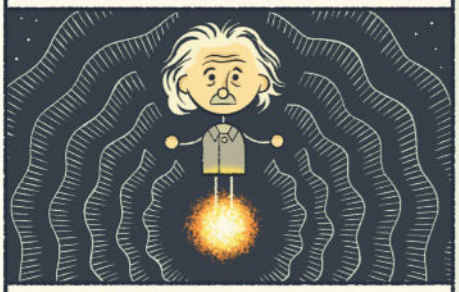
In retaliation to the growing spread of misinformation, he's turning to citizen scientists. "This is a really interesting area to use for science agitation and outreach," says Eisen. Recently, his lab collaborated with the public to find out whether microbes grew differently on the International Space Station. And in an ongoing Kickstarter project called Kittybiome, they raised $23,183 to analyse samples collected from house cats, revealing traits about the feline microbiome. "I think the way to get people to understand the complexity here is to get them to actually do the research," he says. But until the public catches up, Eisen will be on the lookout, ready to debunk and defend.

1. *Most microbes can't be grown in the lab so tracking their DNA in the wild, including the body, is one route to figuring out what they are.*
2. *Amid the germophobes and the micro-biomaniacs, "there's the in-between, which is that this is a complicated ecosystem that most likely changes every day, and the microbes don't care about us, in a positive or negative way."*

GRAVITATIONAL WAVES

Each month we illustrate today's pioneering projects. This issue: how two LIGOs – laser interferometer gravitational-wave observatories – in the US are attempting to observe the vibrations from supernovas for the first time ever

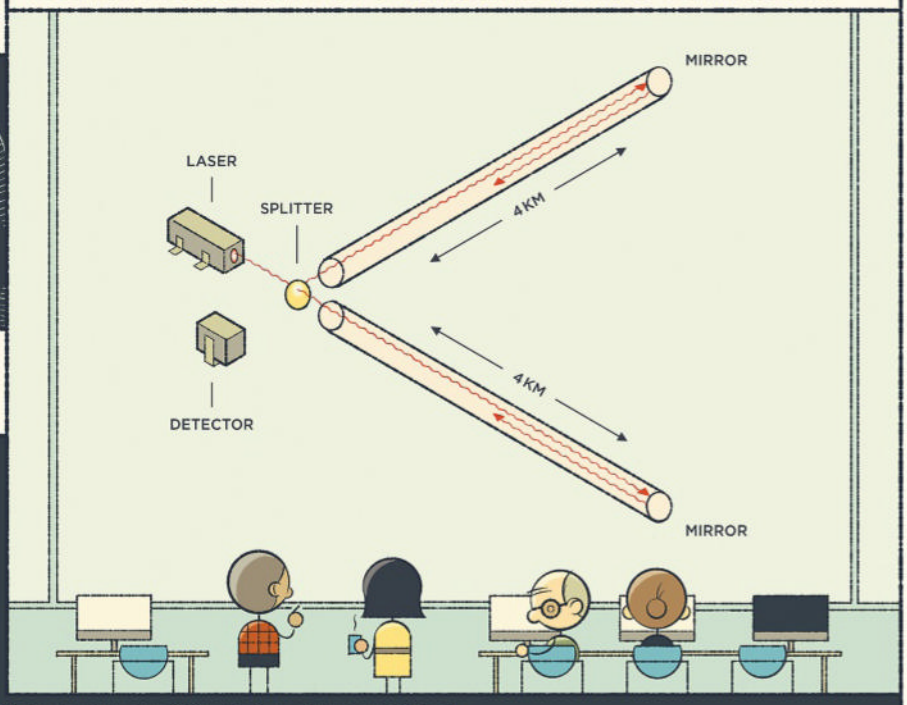
EINSTEIN'S THEORY POSTULATED THE EXISTENCE OF GRAVITATIONAL WAVES – VIBRATIONS PRODUCED BY MERGING BLACK HOLES OR SUPERNOVAS. ***THEY HAVE NEVER BEEN OBSERVED.***



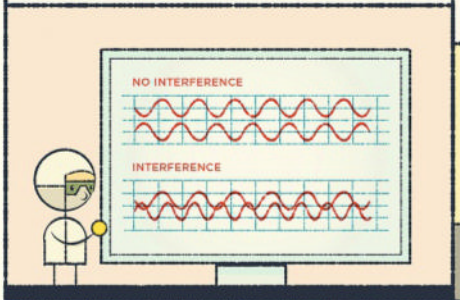
THE ***ADVANCED LIGO*** AIMS TO DETECT GRAVITATIONAL WAVES WITH LASER BEAMS. IT HAS TWO DETECTORS – IN ***LIVINGSTON,*** LOUISIANA AND ***HANFORD,*** WASHINGTON STATE.



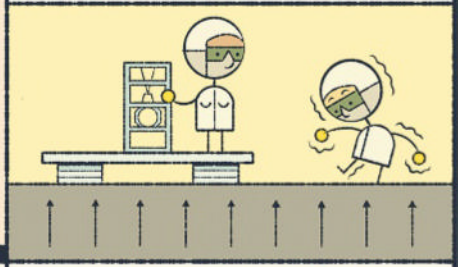
A LENS SPLITS A LASER INTO IDENTICAL HALVES, WHICH RUN DOWN ***TWO 4KM TUNNELS.*** THE BEAMS THEN BOUNCE BACK, IN FRONT OF A ***DETECTOR*** KEEPING TRACK OF THEIR TRAJECTORIES.

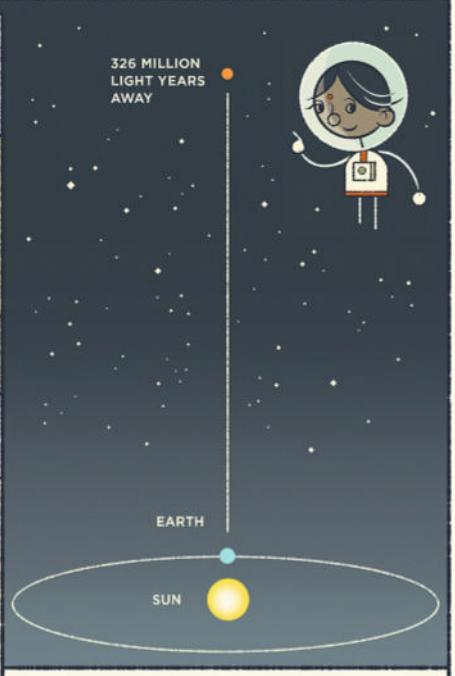


IF A ***GRAVITATIONAL WAVE*** PASSES THROUGH THE LASERS, THEIR TRAJECTORIES WILL BE ***DISTURBED*** – GIVING AWAY THE ***INTERFERENCE.***

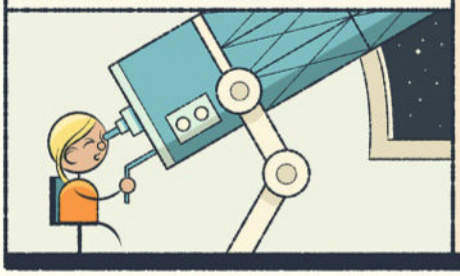


PHYSICISTS NEED TO INFER IF INTERFERENCES COME FROM GRAVITATIONAL WAVES, OR SOMETHING ELSE. ***ADVANCED LIGO*** IS BUILT OVER A MOVING PLATFORM THAT ***CANCELS EARTH-GENERATED VIBRATIONS.***

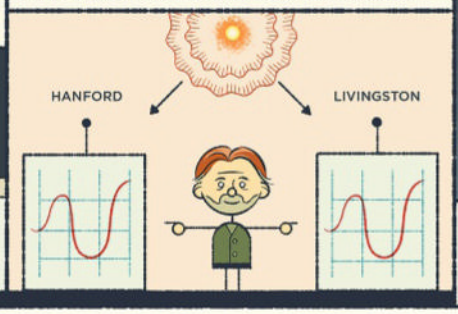




"ASTRONOMERS WILL ALERT US WHEN THEY SEE EVENTS," SAYS ***MIT LIGO LAB DIRECTOR, DAVID SHOEMAKER.*** "WE WILL MATCH THE FREQUENCY GRAVITATIONAL WAVE AGAINST WHAT WE EXPECT FROM THOSE EVENTS."



"IF THE SIGNAL COMES FROM A POINT IN THE SKY, ***WE REQUIRE THAT THE SAME SIGNAL APPEAR IN BOTH DETECTORS,"*** SAYS ***SHOEMAKER.***



ADVANCED LIGO STARTED WORKING IN SEPTEMBER 2015. ***IT CAN SENSE WAVES ARISING 326 MILLION LIGHT YEARS AWAY,*** WITH A MINIMUM FREQUENCY OF 10 HERTZ.

ILLUSTRATION: NICK D BURTON. WORDS: GIAN VOLPICELLI

SAFETY THROUGH DATAFICATION

Your phone's GPS can be used to predict crime, says MIT's Alex 'Sandy' Pentland

MIT Media Lab professor Alex "Sandy" Pentland is a computer scientist and psychologist who studies human behaviour through big data: he calls this "social physics". He uses reality mining – collecting data from devices such as smartphones or GPS-enabled apps to analyse how we act and interact. WIRED speaks to the director of the Connection Science and Human Dynamics labs to discuss what big data can reveal about us, and how it could make governments more accountable.

WIRED: Can you explain precisely what kind of work do you do at MIT?
Alex Pentland: I am interested in technology and society, and how they work together. Right now, the world is becoming datafied: as the world is becoming more digital, we get data from everything, about anything. What I am trying to do is use this data for good. We need the power of data to make things greener and safer, and we want to avoid misuse. I work on data security, data privacy, what you can do with data and, importantly, what data can tell us about ourselves. Data allows us to know a lot about ourselves, but also about our communities, whether they are likely to be full of crime, whether they are likely to be healthy or creative or poor or rich. What it also means is that we can then hold governments much more responsible because you can see all these things.



Fig. 2 *Areas which have the fewest visitors tend to suffer the most incidents of crime*

What data are we talking about here?
All digital systems – for instance, mobile phones or credit-card-payment systems – leave behind little traces. There is data telling when [people] use credit cards, how many people are buying in a specific area, what sort of things they were buying, where were they buying them. And, of course, data from mobile-phone networks. So, companies collect that sort of data, whereas governments collect others on transportation and education. I call them "digital breadcrumbs" because they aren't the things that were intended to be measured — but they're something that came along with the thing that was measured. How many people are in this square, how many people are buying food? Things like that.

What tools do you use to analyse them?
Mostly simple analysis software, general-purpose computation software. But we also generate our own programs. To look at phone data, we developed specific software called Bandicoot[1].

How can you use this data to tell things about us?
One example: we used it to understand which areas in a city were more likely to have more crime and why. We had transportation records and we had mobile-phone tower records showing how many people were in any given location at each time and where they came from, what was their home town. Analysing data helped us make sense of whether there was a lot of diversity in a place, or if just the locals were there. And it turned out that places that are really diverse are the places with the lowest crime rates. More importantly, if you have a place that used to be diverse and suddenly it's just the locals, something's wrong, people fled. We like to joke that you should send social workers and the police there, because you're going to need them soon.

Is the data from social networks useful, too?
I don't tend to use social networks too much, because on social media you tell people what you think they want to hear. It's stuff you tell your friends, and that's interesting, but it's not necessarily true. The way we look at that is that if you know where the social-media data comes from, so again if you have a place that is very diverse – you know that using another source of data – it is also probably a place where social-media posts all sound happy. In that case we know the happiness is real.

How do we tackle the risk of our data being misused?
We set up the Data Transparency Lab with the aim of tracking how the data is used, and who is using it. I'm sure you say "Yes" to apps

that ask to share your data. Do you know what happens with that data? I don't. But there are ways of telling who is using the data: you sample people, and check what information they give out and you sample people who are using the data, and you try to understand whether [the data's owners] knew that.

You said that data could help us hold governments to account. How?
Imagine that, when you run for office, you have to write down the promises you're running on. Then the city appoints an independent commission to evaluate you each month. Then imagine that every country is going to regularly publish all the data I mentioned, and they show, for instance, that crime is growing. So you could use data to hold the politicians accountable.

Could politicians use data to make better choices?
Yes. We still don't understand what policies work, what sort of government is best. We have a lot of stories but we don't know which are true. As you get more data, more experience, you'd go: "Oh! People living this way end up being healthier!" It's the same with crime. There are many theories about crime, and one of them is that if you have a lot of different people from different places there's more of it. Turns out that's wrong. Another theory is that if you have a lot of young people you'll have more crime – turns out that's just a bit true, but not in a significant way. We could get that from just looking at data. **Gian Volpicelli**

1. There are three Bandicoot indicator categories: individual (eg number of calls, text response rate), spatial (eg entropy of places) and social network (eg clustering coefficient).
2. Mozilla, Telefónica, the MIT Connection Science and the ODI are all involved.

PHOTOGRAPHY: DAN COSTA. ILLUSTRATION: MATT HARRISON CLOUGH; PETER DIAMOND



DATA GATHERING

IMAGE OF THE MONTH

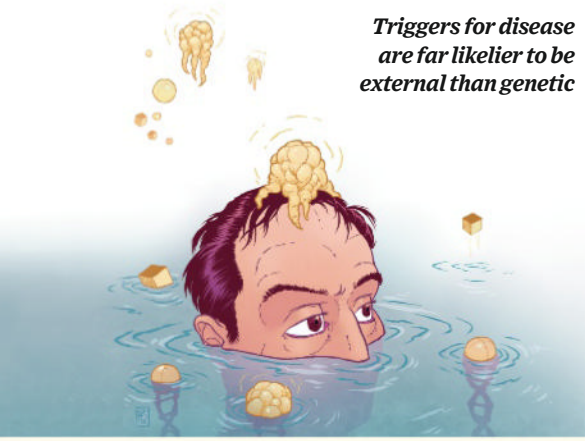
Seals travel far and deep for food. Fitting them with sensors tell us about them and the oceans

This seal is working for science. Researchers from the ten-country project Marine Mammals Exploring the Oceans Pole to Pole (MEOP) have designed waterproof sensors that can be glued on to sea mammals to gather data about the Antarctic Ocean. MEOP-tagged seals have collected over 300,000 profiles of temperature and salinity levels since 2004. Other animals in the project include narwhals and sea turtles. **GV** *meop.net*

EPIDEMIOLOGY

Unnatural borne killers

Triggers for disease are far likelier to be external than genetic



Genetics accounts for ten to 30 per cent of disease; researchers studying the exposome might discover what causes the rest. In 2005, cancer epidemiologist Christopher Wiid invented the term "exposome" to describe all the non-genetic factors influencing human health. "The 'exposome' is a concept that was coined to stress the fact that most of the diseases we know about are due to the environment, not due to genes," says Paolo Vineis, molecular epidemiologist at Imperial College London and co-ordinator of the EXPOsOMICS project, one of two major European initiatives that are now investigating this issue.

Exposome research considers all environmental impacts on human health, identifying their biological pathways in the body and ultimately how they trigger disease. Using tools such as on-body sensors and metabolomics – the intensive study of chemical processes in the body, which can be used to trace changes in the blood – investigators are closely tracking the impact of factors such as air and water pollution, food, exercise and infection on individual health risk. "It's possible that in the future we will have a single sensor able to capture many exposures," Vineis says.

Ultimately, the current research will yield a vast collection of baseline data that will power more work on the under-studied environmental triggers of disease. "After the genome, we propose the exposome," says Vineis. **EB**

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03.15 PUSSY RIOT – THE WIRED RULE BREAKERS' GUIDE



02.15 NETFLIX – HOW REED HASTINGS BEAT AMAZON & YOUTUBE



01.15 STEPHEN HAWKING – EVERYTHING IN THE UNIVERSE EXPLAINED



12.14 BUCKLE UP! THE WORLD'S FIRST 1,000MPH CAR



PHOTOGRAPHY: AORTA

The Noma test kitchen, Copenhagen

WIRED

The future food issue

Inside the world's most innovative restaurant

Cultured meat

The startup taking on Big Food

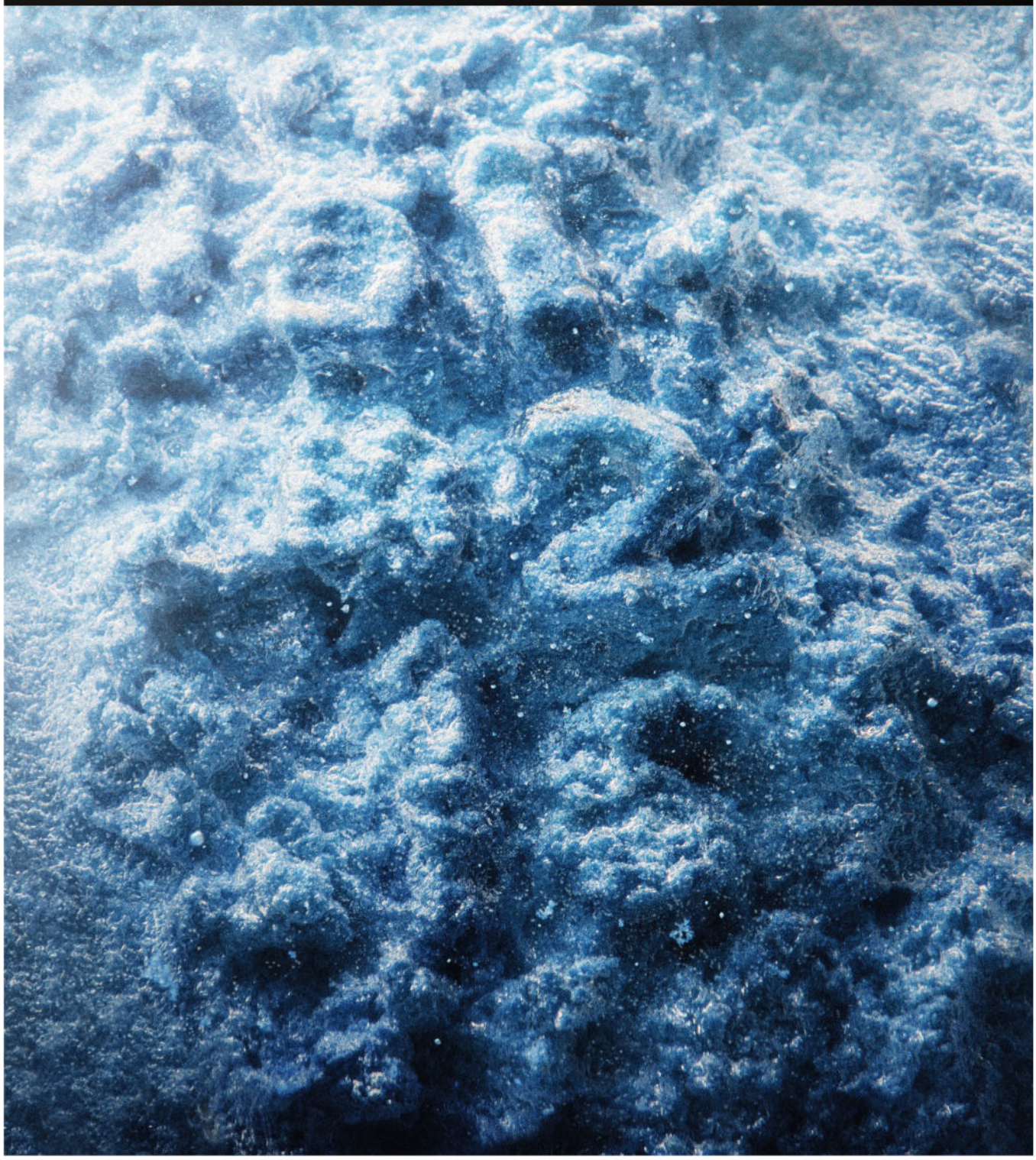
Vertical farming

Where to eat the very finest insects

Umami!

The March issue, out Feb 4

FEATURES



PHOTOGRAPHY: KYLE WILKINSON. CREATED USING HYDROPHOBIC SAND SUBMERGED UNDERWATER. SHOT AT 1/125SEC F.20 AT 178MM WITH EXTENSION TUBES AND A SOFTBOX

"I would go to bed and think: 'Holy shit, we shot a *Millennium Falcon* chase sequence today.'" J.J. Abrams, p130

J.J. ABRAMS REIMAGINED AS AN IMPERIAL STAR DESTROYER 130

BY BEN MILLAR AND JAMES DAY





THE EMPIRE IS BACK

FOUR YEARS AFTER DISNEY SNAPPED UP LUCASFILM FOR $4BN, STAR WARS IS BACK AND BIGGER THAN EVER. IN THIS SPECIAL FEATURE, WIRED TALKS TO DIRECTOR J.J. ABRAMS AND HIS TEAM ABOUT MAKING THE FORCE AWAKENS, THE SPACE SAGA'S MUCH ANTICIPATED SEVENTH EPISODE

BY
OLIVER FRANKLIN-WALLIS
PHOTOGRAPHY:
JAMES DAY, JULIAN HEATH & DAN WINTERS

A NEW HOPE

A not-very long time ago (2011), in a galaxy not very far, far away (ours)... It is a dark time for *Star Wars*. The planet-destroying film franchise that spawned a galaxy-sized global fan base and a multi-billion-pound empire of toys, games, lunchboxes and spin-offs has fallen into darkness. Despite the prequel trilogy being a $2.5 billion (£1.63bn) box office hit, the fan backlash – spiteful of Jar Jar Binks's bumbling, godawful senate politics and the sheer lameness of midi-chlorians – turned a rightly disheartened Lucas into little more than the subject of *Family Guy* parodies.

But then: a new hope! In October 2012, George Lucas retired and sold Lucasfilm – and with it the rights to *Star Wars* – to Disney for $4 billion. And, like Anakin Skywalker's lightsaber, the franchise was passed on to two new wards: producer and new Lucasfilm president Kathleen Kennedy and director J.J. Abrams (*right*).

Star Wars: The Force Awakens, which opens in the UK on December 17, will kick off not just a third *Star Wars* trilogy, but a vast, Marvel-style cinematic universe. Movies confirmed so far: 2016's *Rogue One* and an as-yet-untitled Han Solo movie due in 2018. *Star Wars* isn't just back, it's about to be all consuming. (That's no moon – it's Disney's marketing budget.)

Here's what we know: *The Force Awakens* takes place 30 years after the original trilogy. The original cast – Harrison Ford (Han Solo), Carrie Fisher (Leia Organa), Mark Hamill (Luke Skywalker – at least, we think), Peter Mayhew (Chewbacca) – are all back. They're joined by a cantina-ful of some of Hollywood's brightest young stars: Daisy Ridley as heroine Rey, John Boyega as stormtrooper Finn, and Oscar Isaac as X-wing pilot Poe Dameron. Then there's Adam Driver as the big bad, Darth Vader-like, crossguard-lightsaber-wielding Kylo Ren. (Not to mention a supporting cast including Andy Serkis, Gwendoline Christie, Lupita Nyong'o, Domhnall Gleeson and Max von Sydow.)

And finally there's Abrams, a lifelong *Star Wars* nerd who, after reinventing *Star Trek*, is now tasked with directing one of the most discussed new films of all time. To do so, he – alongside a cast of producers and *The Empire Strikes Back* writer Lawrence Kasdan – has gone back to what made *Star Wars* great, embracing physical sets, shooting on 35mm film and, naturally, bringing back composer John Williams to create a score worthy of the original. To kick off WIRED's *Star Wars* special, we sat down with Abrams in Los Angeles to talk about the most difficult job in film-making.

Dim the lights. Roll titles. Trumpets blare. *Star Wars* is back.

WIRED: First, the spoilers. You've been very clear – including an essay in US WIRED – about the importance of mystery in storytelling. But with *Star Wars*, not only does the internet demand a stream of news, but you've got toys, novels and tie-ins all giving details about the film away.

J.J. Abrams: Sure. It's crazy.

As someone who is quite protective of secrets, how has that been for you?

It's in my nature to keep things as quiet as possible. When I was a kid, it was very hard to even get information about movies, and if you did you had to actively go and seek it out. Now we are force-fed stuff we might not even want to know.

I also realise I am learning a lot, and I don't have to keep as much secret as I might want to. So for me, this has been partly an act of education and compromise: how do we show more that I might want to, but not so much that we ruin the experience? I've got to tell you, I'm incredibly grateful to [Disney CEO] Bob Iger and [Disney chairman] Alan Horn, not only for the experience of making this movie, but because they don't want to reveal much either. I was really afraid that I would be in the situation with a studio that was dying to put it out there, and do what I can't stand, which is make trailers that tell you everything, then you're literally watching the movie to fill in the blanks.

George Lucas is a very visual director – he talks about some of his films being visual tone poems. When you came >>





THE NEVER-ENDING EDIT

George Lucas has tinkered with *Star Wars* so much you can't actually view the original screened versions any more. Thankfully, fan Petr Harmacek has done what Lucas deemed "too expensive": created an HD version of the trilogy, but with all of the changes stripped out. The "Despecialized Edition" took Harmacek, 27, six years, combing through old negatives, DVD materials and custom mattes in order to refine and restore each original scene.

"To supress the originals is to bury the work of artists who spent thousands of hours working on effects and other art," says Harmacek.

WIRED tracked some of the changes between the 1977 release of *Star Wars* and the 2015 version (now called *A New Hope*). **Stephen Kelly**

● **1977 ORIGINAL (*STAR WARS*)**

● **2015 BLU-RAY (*A NEW HOPE*)**

INFOGRAPHIC: VALERIO PELLEGRINI

TYPE OF CHANGE

1. Added scene
2. Digital addition
3. Digital addition/rehaul
4. Digital alteration
5. Digital alteration/enhancement
6. Digital alteration/rehaul
7. Digital enhancement
8. Entire shot digitally rehauled
9. Miscellaneous change
10. Shot reframed
11. Shot reframed/digital additions

START 00:00:00

00:00:15

7

Original Lucasfilm logo

Lucasfilm logo updated with modern version

00:00:45

8

Film is titled *Star Wars* in its opening crawl

Title updated as *Episode IV*, with the subtitle *A New Hope*, on the film's theatrical re-release in 1981

00:15:40

7

Shot of the jawa's sandcrawler on the move

Shot is digitally rehauled, with new, brighter sky, new terrain and a different framing

00:16:50

9



Shot of jawas setting up droids outside the Lars homestead

The shot has been scaled down, with more moisture vaporators added to the background

01:20:18

3

The dianoga garbage monster's eye is a prosthetic

The dianoga's eye has been digitally updated to blink and move

01:08:49

3



Flashes can be seen as blaster bolts hit Imperial officers

The impact of blaster bolts have been removed, presumably to make it less graphic

01:06:00

4

The *Millennium Falcon* - a matte painting - sits in the Death Star hangar bay

The spaceship is now a digital model and the hangar has been redesigned

00:59:52

6



The droids and Chewbacca play dejarik, made using stop-motion

The stop-motion elements have been digitally remade

00:59:09

3

Alderaan is blown up by the Death Star

Alderaan explosion is replaced with blast that is crisper and including a shockwave ring

01:22:23

8



A stormtrooper hits his head on a door when storming a control room

This blooper has now been acknowledged with a "bonk" sound effect

01:25:42

8

The tractor beam display is in English

The tractor beam display has been changed from English to Aurebesh, the *Star Wars* font

01:27:41

7



Han Solo runs into five stormtroopers

The scene has been enlarged with a digital matte set, bluescreen and a lot more stormtroopers

01:38:09

7

The *Millennium Falcon* approaches Yavin IV

Yavin IV has been digitally updated, and the *Millennium Falcon*'s approach made more dynamic

01:38:26

2

A Rebel sentry scans the empty sky before the *Millennium Falcon* docks at the base

A computer-generated *Falcon* was added to the shot to give the sentry something to do

00:02:26

6



A Star Destroyer can be seen in pursuit of a Rebel ship

The Star Destroyer's engines have been digitally enhanced to burn brighter

00:03:25

6

The Rebel blockade runner can be seen docking with the Star Destroyer

The docking animation has been smoothed out

Jawas carry R2-D2 to their sandcrawler in broad daylight

The sky in this shot has been changed to twilight

3

00:13:09

00:09:00

3



R2-D2 and C-3PO's escape pod is blue

The escape pod is now grey

00:10:17

3

C-3PO stands alone on the sand dunes of Tatooine

Skies of Tatooine are now cloudy and the sand dunes look different

R2-D2 trundles through a drab canyon

The horizon has been lowered in order to add in a digital sunset

3

00:11:21

6

R2-D2 beams a hologram message from Princess Leia Organa

The hologram and R2-D2's beam have been made brighter

00:21:08

3



Luke Skywalker stares out at the twin suns of Tatooine

The setting suns have been digitally redrawn, and there is now red cloud surrounding them

00:25:40

3

R2-D2 hides from the sand people behind a crevice

R2-D2 now hides from the sand people behind rocks

00:29:14

7



Simple establishing shot of Obi-Wan Kenobi's hut

The shot has been rehauled, showing off more of Tatooine

00:32:34

7

Mos Eisley in the distance is a static matte painting

Original matte painting has been rehauled and now features air traffic

00:42:36

1



n/a

A new scene where Han Solo is confronted by a computer-generated Jabba the Hutt has been added

00:52:41

3

Han Solo shoots Greedo

The scene is altered to make Greedo shoot first and Han Solo second, presumably in self-defence

00:50:51

2



Shot of a stormtrooper making enquiries outside the Cantina

An extra stormtrooper and a dewback have been added

00:47:40

3

A stationary model dewback sits outside the Mos Eisley Cantina

The model dewback has been replaced with a digital version

00:44:31

2



Luke's landspeeder enters Mos Eisley, with a few people and droids milling around

The sequence has been heavily updated with multiple digital elements added

00:42:58

1



n/a

A deleted scene where Luke meets childhood friend Biggs Darklighter has been reinserted

01:43:17

7

A squadron of X-wing fighters, depicted as distant flashes, launch from the Rebel base

The X-wings' launch has been made more elaborate

01:45:03

5



The Rebel fleet approaches the Death Star

The shot now features more spaceships, and Yavin IV has been digitally added

01:45:22

7

Three X-wings dive down towards the (unseen) Death Star surface

The shot has been rehauled to show digital X-wings diving down to a huge, visible Death Star surface

01:46:21

7



A languid dogfight between Biggs and a TIE fighter is seen in the distance

Sequence has been remade with digital elements

01:48:20

6

Three TIE fighters are surrounded by a garbage matte, used to remove superfluous items from a shot

The garbage matte has been digitally removed

01:50:29

FINISH
01:58:46

to *The Force Awakens*, did you have certain visuals, such as the crashed Star Destroyer, in mind?

Some of the earliest inspirations came out of conversations with Larry Kasdan, [producer] Bryan Burk, [writer] Michael Arndt, Kathy Kennedy, [producer] Michelle Rejwan and [production designer] Rick Carter. We would all sit around and talk about things that we were interested in seeing – there was no story in place.

Quickly, certain things started popping up. Sometimes it was imagery, sometimes it was a character, sometimes it was a situational thing. The idea of someone who found themselves in a desperate situation wearing a stormtrooper outfit. Was he a spy? Was he a defector? We didn't know at first, but there were images that started to feel like, "Oh, come on, that's hard to deny." The idea of a battlefield wasteland, where there had been a titanic battle between the Empire and the Rebellion. Whether they would end up in this movie or not, we didn't know.

How did the process for this vary from your other films?

It's always the same process, even if it's a *Star Wars* movie – you find yourself attracted to certain ideas, certain feelings, things that are disparate and disconnected. The leap of faith that we all took was that these would start to assemble. Over time, certain moments that had inspired us enormously became secondary and tertiary to the plot. And often we'd forget that a moment started out as "Wouldn't it be incredible if?" What was fun, sometimes when we were shooting – and even now when we're looking at visual effects reviews – a moment that is part of a much larger piece, you suddenly see it and you think, "Oh my god, that's so cool!" and you remember that's what inspired the scene to begin with.

'IS DARTH VADER SEEN AS SOMETHING TO RESENT, OR AS A MARTYR? IS HE SOMETHING TO ASPIRE TO?'

One of the most memorable things about the first *Star Wars* trilogy was the used universe: that lived-in feel that fired so many imaginations. For this film, the universe has changed. Fans are going to analyse every little detail and try and connect it to the earlier films. How much attention do you have to pay to those details?

What you're describing is true, both in what you see, and also in the history of the characters. Everything that they are is standing on the shoulders of what has come before it. And it's not just how those things got there – a Star Destroyer crashed in the desert – but things like: what's the legacy of Darth Vader? We were in the room when his mask came off, but there were only two people in that space that we know of when he saved his son. Who reported that? Is he seen as something to resent, or as a martyr? Is he something to aspire to? That idea of what has come before, and how has it decayed or been distorted. The fascinating thing for me was: what has transpired between what we know, and what is now?

There's a young generation of characters in this movie who have not seen *Star Wars*. By that I mean they may live in a place that resembles it, they may have some existing knowledge of it – but they've never seen it. And that idea of: what about the young characters who find themselves in the middle of a *Star Wars* adventure? Characters who aren't prepared for it, but find themselves as absolutely desperate as any *Star Wars* character – and desperation for me is the key quality that every character in *Star Wars* has. That, for me, was a thrilling way in.

It's interesting you mention desperation. You don't hear people say a lot about it, but one of the key aspects of the original films is comedy.

Of course! What's funnier than desperation? I mean, C-3PO might be the most desperate character in the movie. Han Solo is desperate to make money. Luke's desperate to get the fuck off that farm. Leia's desperate to get the plans to her father. Vader's desperate to get the plans back from the Rebellion – everyone is desperate. And it is the desperation that makes for some of the funniest moments in the movie. Han accepting this job because he's desperate to pay back Jabba? That's perfect comedy. Then their desperation when they're all together in the middle of that trash compactor? It is a series of absolutely extreme, ridiculous, desperate moments. But I will say, when I get asked again and again »

SKETCHING VADER'S BACKSTORY

Darth Vader stares out of a Star Destroyer window, having just heard the name Luke Skywalker for the first time. "I have a son," he seethes, the glass cracking with rage. "He will be mine. It will all be mine."

It's a dramatic moment – but one you will never see on screen. Instead, you'll need to read Marvel's *Darth Vader*. Set between *A New Hope* and *The Empire Strikes Back*, it's one of several new Marvel comics tasked with filling in the gaps created when Lucasfilm somewhat controversially reset the *Star Wars* "expanded universe" in 2014.

"The difference between Vader in those films is enormous," says writer Kieron Gillen, 40. "He's just discovered the last 20 years of his life have been a lie. 'I thought I killed the woman I loved, but she had a son who has been hidden from me.' That's about as Greek tragedy as it gets."

Gillen, best known for independent comic *The Wicked + The Divine*, was signed up after Marvel (owned by Disney, like Lucasfilm) won the licence back from Dark Horse Comics in 2014. Writing Darth Vader came with strict guidelines as to what the galaxy's most infamous absent father can and can't do. "I found out as I went along," Gillen says. "I know the period, though. I'm not going to have a story where Vader goes DJing for six months."

So, just how do you take on the biggest badass in the galaxy? "The trickiest thing is walking a line between understanding what drives him and humanising him too much," says Gillen. "I don't do internal captions for Vader. You just see a lot of panel flashbacks and a lot of him staring into the distance. It's all implied. This is why [Vader's accomplices] are kind of fun. You should be scared to be in the same room as him." **Stephen Kelly**









Artists Salvador Larroca and Adi Granov brought *Darth Vader* to life



1 _ Hero Mashers





2 _ Micro Machines



3 _ Deluxe figures



4 _ Regular figures



5 _ Titanium Series



6 _ Lightsabers and Nerf guns



7 _ Micro Machines Playsets

PREPARE FOR STORE WARS

Star Wars toys have always been big business. In 1977, the phenomenal toy sales around the first film caught everyone off guard – not least Fox, which signed away full merchandising rights to George Lucas as part of his compensation package. (Lucas's faith in his vision paid off: Kenner, the original manufacturer of the film's toy line, was unable to meet Christmas demand and was forced to sell an "Early Bird Certificate Package", essentially an IOU.) In 2012, Lucas Licensing placed total merchandising sales at more than $20 billion.

"There's real cross-generational appeal," says Steve Evans, *Star Wars* design director at Hasbro, which bought Kenner in 1991. "You see 40-year-old collectors alongside four-year-olds waving lightsabers."

For *The Force Awakens*, Evans's team has designed scores of new toys – more than 90 have been unveiled so far. The design process began over 18 months ago. "We start off working very closely with Lucasfilm, bouncing ideas back and forth, always going to them for approval," says Evans, 42. "We get assets to work with so we can make sure the toys are aligned. But in terms of special previews? Nope. We're in line with the rest of you."

Initial development takes place digitally: "We have characters and props scanned in a 3D-scanning booth," explains Evans. Once the look of the toy is agreed, each undergoes play-testing. "We 3D-print the full-size model straight from the digital file," says Evans. "This means we can give it to kids to see how it fits their hands."

Evans tips the Bladebuilders customisable lightsaber range as a likely best seller, but his favourite remains the traditional 9cm action figures. "I'm the father of two daughters,' he says. "And it's been exiting see them engage with Rey's figure." **Kathryn Nave** *hasbro.com*

what is the fundamental element to *Star Wars*, my answer is always that it is a movie that had such incredible humour. The heart of that movie was so remarkable. Yes, the music was incredible, yes the visuals were amazing, yes the technology was incredible. Everything that George did right was winning the lottery – it's an impossibility, the odds that he succeeded in that. But the humour, that was the way in.

You can't talk about *Star Wars* without talking about the music. What was it like for you, a lifelong John Williams fan, to hear him playing you the soundtrack for the first time?
Unbelievable. I mean, *unbelievable*. There's John Williams playing me music on the piano, in his house, and I'm extrapolating it into what it's going to be when a 110-piece orchestra is going to be playing it. It's like seeing those old Abbey Road behind-the-scenes films of Paul McCartney playing a song to George Martin for the first time, and he's like playing the guitar but making a French horn noise, and you're like, "Oh my god, this moment is something historic." To say mind-blowing doesn't even touch the impossibility of it. Especially given that I grew up listening to his music, instead of downloading or watching DVDs or VHS tapes, because none of those things existed when I was a kid.

***A New Hope* was, technologically, one of the most groundbreaking films of all time. But on *The Force Awakens* you've gone back to 35mm film and practical effects. How do you balance capturing the feel of the original trilogy while keeping that legacy of pushing boundaries?**
The thing about this movie, going in, is that I knew there were going to be thousands of computer-generated [CG] shots in the film. The work that Industrial Light & Magic is doing, that Roger Guyett our special effects supervisor, is doing, is groundbreaking – they're using simulations and all sorts of techniques that haven't been done before, partly because we did do as much as we could without CG.

Why's that?
We desperately wanted there to be a standard of reality and authenticity, so that everything that was CG had something to adhere to and a standard that it needed to achieve. The inspiration was that feeling I had, that Kathy had, Larry Kasdan had, watching those original films. When you are in the middle of Tattooine, and you're looking out at the binary sunset, the amazing thing was yeah, they put in another setting sun there, but there is no question that is an actual human being standing in an actual desert location. When you're on the frozen planet of Hoth, when you're in the forest of Endor – again and again and again, there were examples of physical, tangible reality.

The brilliance of what George did was in part using real-scale so judiciously that you would then buy things that were illusions. He was the ultimate magician in being able to know exactly where your eye was looking when he would palm the coin and make you believe it was in the other hand.

What does that then give you as a film-maker, when you're on set?
It was enormously valuable for the actors, for the camera, for the look of the movie. And it allowed us to create characters and sets and locations and props and explosions and things that added a level of authenticity that is not always quantifiable, but without question is hugely important. So, for example: if you look at the first movie, they didn't have lightsabers that lit up – so there's no interactive lighting, there wouldn't be. Does it mean those scenes aren't among the greatest scenes ever filmed? No. But what an amazing thing to see our prop department created these ridiculously powerful lightsaber props that would allow us to do scenes where there was interactive lighting. And what that did was allow us to do things we probably never could have anticipated, and we couldn't have even replicated in CG, where you literally can see the light not just on the characters' clothes and on their faces, but in their eyes. It's just an amazing thing to see. Small detail. Does it make a scene good? No. But is it a wonderful piece of reality to have on your side? Yes. »

'WE WANTED THERE TO BE A STANDARD OF REALITY SO THAT EVERYTHING COMPUTER-GENERATED HAD SOMETHING TO ADHERE TO'

THE DROID FACTORY

You can't have *Star Wars* without droids. (Oft-overlooked fact: aside from Anakin Skywalker/Darth Vader and Obi-Wan Kenobi, R2-D2 and C-3PO are the only characters to appear in all six films.) In *The Force Awakens*, Threepio will once again be played by Anthony Daniels. But to bring back Artoo, J.J. Abrams turned to two British superfans, Lee Towersey (*opposite, left*) and Oliver Steeples (*right*).

The pair are members of the R2 Builders Club, a worldwide community of hobbyists and makers dedicated to creating movie-accurate droids, which they tour at fan events. "We were at Star Wars Celebration in Germany in 2013, and Kathleen Kennedy was there," says Steeples, 40. "We had a chat with her, and said, 'If you need droids for *Episode VII*...'" As it turned out, they were just the droid-makers Kennedy was looking for. A few weeks later they were on set at Pinewood Studios. "It's still unbelievable," says Towersey, 45.

Although the pair's own R2s are remarkably accurate, they weren't quite up to scratch for the film. So they returned to the original designs from *A New Hope*. "Club" R2s are usually made from styrene; *The Force Awakens*' unit was custom-built from fibreglass and aluminium, with parts 3D-printed in the film's creature workshop. The new droid is powered by hub motors in its base, allowing for more precise control during action sequences. (Unlike fan droids, the filming units are also silent; R2's beeps and whistles were added later.)

"We were hiding behind boxes, because they had cameras all over the set, with explosions going off and droids getting blown up," says Steeples. Not bad for two lifelong fans. "*Star Wars* – that's what childhood was for me," says Towersey. "It doesn't get any better than this." **OF-W**



PINEWOOD'S PROPS WING

1 _ Lightsaber. But who does it belong to? WIRED and Disney are remaining tight-lipped here to avoid spoilers
2 _ First Order trooper outfits
3 _ Kylo Ren's lightsaber
4 _ X-wing starfighter pilot helmet
5 _ TIE fighter pilot helmet
6 _ Trandoshan doubler on target pistol
7 _ Poe Dameron's X-wing starfighter helmet
8 _ X-wing starfighter pilot helmet
9 _ Snowtrooper helmet
10 _ Captain Phasma's helmet
11 _ Han Solo's BlasTech DL-44 blaster pistol
12 _ Eirriss Ryloth Defense Tech Glie-44 blaster pistol
13 _ X-wing starfighter pilot helmet
14 _ General Hux's hat
15 _ Flametrooper helmet
16 _ Sarco Plank's SoroSuub JSP-14 pistol
17 _ Blaster pistol
18 _ Blaster pistol
19 _ Stormtrooper Sonn-Blas F-11D blaster rifle
20 _ Poe Dameron's BlasTech EL-16HFE blaster rifle


1 _


2 _


4 _


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17 _

3 _



DRESSING THE FIRST ORDER

When costume designer Michael Kaplan was working out how to update the stormtroopers for *The Force Awakens*, inspiration came from the phone in his pocket. "With time, simplification occurs," says Kaplan. "Because the stormtroopers are hard, white and plasticky, my thoughts went to Apple."

Where once were bumps and nodules on the outfits, there are now clean lines and floating faceplates. "The original stormtroopers were vacuum-formed," says Kaplan. "That process required a thinner plastic to be heated and moulded. These are much harder [cast in polyurethane], so they don't crack. They're tougher and more flexible."

For the film's villain Kylo Ren, Kaplan had the job of evoking the past without directly copying it. "Kylo Ren feels a kinship with Darth Vader, so there is a bit of emulation," he says. Particularly in the mask, for which J.J. Abrams's specification was that Kaplan create "something that would make a child want to see the movie".

One of the film's most striking costumes was never originally supposed to be used. The elegant silver armour of Captain Phasma, a First Order officer played by Gwendoline Christie, started as a whim of Kaplan's. "I loved the idea of taking a stormtrooper into the world of armour," he says. "The concept artist took my sketch and came up with a beautiful illustration which I hung on the wall of our design room. One afternoon Kathy Kennedy came by, and exclaimed, 'That's fantastic.' J.J. loved it too, so he created the role of Captain Phasma to wear it."

Christie covered in mirrored metal might have caused headaches for cinematographers, but "that's not my responsibility", Kaplan laughs. "She looked wonderful." **Olly Richards**

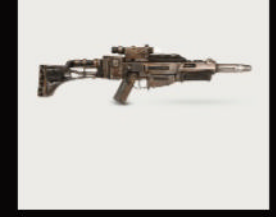
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20 _



As one of *The Force Awakens*' two production designers, Darren Gilford was tasked with resurrecting *Star Wars*'s most iconic space ship: the *Millennium Falcon*. "We quickly realised that there wasn't one design of the *Falcon*, there were three," Gilford explains. "It was subtly different in each of the original films. For example, the cockpit's bigger in *The Empire Strikes Back* – they extended it by two or three feet because they had to get so many people in it."

Fortunately, as well as having on-set expertise from veteran crewman Mark Harris, who actually built the *Falcon* for *Empire*, Gilford's team has access to all the original photographs and blueprints. "So we got to build the perfect *Falcon*," says Gilford. "Making sure all the dressing, the ageing, every detail was as close as possible to the original." He was also given a personal request from ex-carpenter Harrison Ford: "The set decorators chintzed out – they didn't put springs in the toggle switches [in 1976]," Ford told Gilford. "Make sure the springs are in." He did, and was pleased to later see Ford flip the switches without a hitch.

Instead of relying on pixelated world-building, some scenes used old-fashioned painted backdrops. "That's really a lost art," says Gilford. "It was the perfect reason to return to Pinewood, to connect with that style of craftsmanship. It's the only place in the world where you can do that kind of work. We built this incredible, huge forest on set, and the entire stage wall was 360°, a giant painting of the forest that extended off to infinity. And it works so beautifully."

Such work, he says, leads to better performances. "Any time you can put an actor in an environment where they're not having to second-guess what's going to be composited around them is going to help. That's always the desire, but it's not always the case, financially. But here we were really able to find that blend." **Alex Godfrey**

THE SPIRIT OF RALPH MCQUARRIE

Original trilogy conceptual designer Ralph McQuarrie died in 2012, but his legacy looms large. "When we were updating the X-wing we put two engines on either side and split them in the middle," says Gilford. "Then something in the back of my mind said, 'I've seen that before.' Sure enough, I went back to one of Ralph's classic paintings, and he had done a version like that. I pulled that image out in the next meeting with J.J., and he said, 'That's it. If Ralph had that idea, it's good enough for us.'"

CONSTRUCTING A NEW LIGHTSABER

"In the original films the lightsabers were metallic and they had to rotoscope glowing lights on to them," explains Gilford. "It was all comped in afterwards. This time, however, with LED technology, they were able to make real light-up lightsabers that would interact. When they clashed with each other they would flash and spit. I'm sure they'll be touched up in effects, but you get this incredible interaction, light bouncing off the characters in-camera, so it feels so much more real. It's pretty spectacular."

PHOTOGRAPHY: LUCASFILM 2015



REDESIGNING THE FASTEST HUNK OF JUNK IN THE GALAXY

WHAT A PIECE OF JUNK: THE USED UNIVERSE

George Lucas's original philosophy was that *Star Wars* should feel like a "used universe" – worn, torn and battle-bruised, and Abrams challenged his crew to reclaim that. "He wanted to make sure that things blended seamlessly, to feel real and tangible," says Gilford. "Rey's speeder is supposed to look like some kind of tractor: the goal was to give her a vehicle that felt like a beat up, broken-down, hand-me-down piece of junk. She's not driving a Ferrari, she's driving her old pick-up truck that's on the farm."



We had the cockpit of the *Millennium Falcon* outdoors on a gimbal. We didn't have to do it outdoors, or on a gimbal. The only reason we did that was we knew you can't fake sunlight. It's one thing to have a big BB light on a dolly moving back and forth, it's another to have actual sunlight. When you see the sequence of Daisy Ridley in that cockpit, the light that is interacting with her is sunlight – and it just simply looks better.

When we're outside in the forest in Wales; when we're on ice in Iceland; in Skellig; even in Pinewood Studios, when we built exterior sets, we're actually at scale outdoors. The scene where you see the rally of the First Order – we could have shot that inside somewhere, but we shot it outdoors with enormous scope and crazy big cranes. We filled in the vast majority of the characters and extended the set [with CG], but it was amazing how much was physical and real. We had hundreds of stormtroopers. We didn't have 100,000, but we had enough to give the movie a reality.

Being able to use CG to remove things such as puppeteers, arms and controls and strings and legs of people that were under creatures, instead of adding things, was priceless. We were in a desert in Abu Dhabi with five guys inside a Hopabor costume – in between takes they would shove an air conditioning unit up its ass to cool the guys down so they didn't die in 50°C heat. But you had this physical, tangible creature right there that John Boyega could interact with. Could it have worked otherwise? Of course. We've all seen movies that have done that. But by making it physical and real, I would argue it made that scene better. None of this makes it a good movie, but some of it can prevent it from being a bad one.

As a lifelong *Star Wars* fan, you've got this cast of legends – Harrison Ford, Carrie Fisher, Mark Hamill – but also a young cast. How do you direct them without treating them differently?

It's a great question. The key to doing this movie, for me – and I think I share this exact sentiment with everyone else in the crew – was to acknowledge, embrace and appreciate your fandom, and then put it in your pocket. I couldn't be on the set and be a fanboy. I needed to be a director. Harrison, Carrie, Mark, Anthony [Daniels], Peter – none of the original actors wanted a fanboy to work with. They needed someone who would give them criticism, feedback, notes, ideas. So while there were moments – almost every day – where I would find myself

'I NEEDED TO BE A DIRECTOR. NONE OF THE ORIGINAL ACTORS WANTED A FANBOY TO WORK WITH'

gasping that it was happening, I would have to suppress that and do the job required, because no one, and certainly not the movie, would benefit from my being blinded by the love of *Star Wars*.

There were nights where I would go to bed at night and just think, "Holy shit, we shot a chase sequence in the *Millennium Falcon* today." But I was holding my breath all day because I couldn't let myself bathe in the impossibility of what we were doing. The young cast was so helpful, because as brilliant as they are – and they fucking are – they were game as hell to do the best possible job. And I think they were as inspired by the original cast as the original cast were inspired the young cast.

You won't be directing *Episode VIII*, but you will be executive producing.

Eight and nine, yep.

How does it feel to be giving that up, while also knowing that this will follow you around forever? You're always going to be the guy that brought back *Star Wars*.

I hope people like what they see. I hope it's something that I won't regret. But I also find a kind of comfort with [*Looper* director] Rian Johnson taking over on the next movie. I'm one of a handful of people to have carried this burden. It's a wonderful and amazing burden, but it's still a challenge to do something worthy of what people deserve. So I'm very grateful for Rian and now Colin [Trevorrow (*Jurassic World*), who will direct *Episode IX*] coming on board.

It's been George for a long time. And it's only been George. And I think now, with Cathy running Lucasfilm, it's going to be a big group of people – and any interest people have with my involvement will soon fade, and it will become someone else in this chair.

Oliver Frankin-Wallis is assistant editor at WIRED, *and edits the Play section*



The NHS Blood & Transplant facility in Bristol, where donated blood is screened. A British team called Novosang wants to render this process obsolete



147 | BY | **JOÃO MEDEIROS**

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BLOOD SIMPLE

DONATIONS AREN'T ENOUGH TO SATE THE WORLD'S NEED FOR RED BLOOD CELLS. SO A UK FIRM IS WORKING TO GROW THEM IN A LAB

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BACK IN 2007, THE US DEFENSE Advanced Research Projects Agency (Darpa) issued an open call for a project. It required applicants to make a bioreactor that could produce an unlimited supply of blood from stem cells. The machine would be 1.3m^3, roughly the size of 2.5 domestic washing machines, and hardy enough for it to withstand being parachuted into a battlefield and still function. The output was to be automatically packaged in standard blood bags. Darpa was offering a grant of $49 million (£32m). And the machine had to be completed within 27 months.

One of the teams to apply was a consortium of British academic groups and blood services. The senior figures in the group included Willy Murphy, medical and scientific director of the Irish Blood Transfusion Service; Dave Anstey, a researcher at NHS Blood and Transplant; Marc Turner, medical director of the Scottish National Blood Transfusion Service; and Joanne Mountford, a biomedical stem-cell researcher at the University of Glasgow.

"The majority of us in the consortium were already working on adult stem cells but we hadn't put the idea together of using our technology to make red blood cells," Mountford says. "Of all the tissues that you might have wanted to make from stem cells, you would have argued that red blood cells were not one at all, because we have a perfectly good supply of them already. Why reinvent that wheel? What we really need is neurons, what we really need is liver cells, because we don't have sources of those. But we started to realise that the idea of making blood in a machine – essentially a slot machine for blood – actually made sense. It was always going to be a massive challenge biologically and from an engineering point of view, but we could see that it might be doable, at a cost."

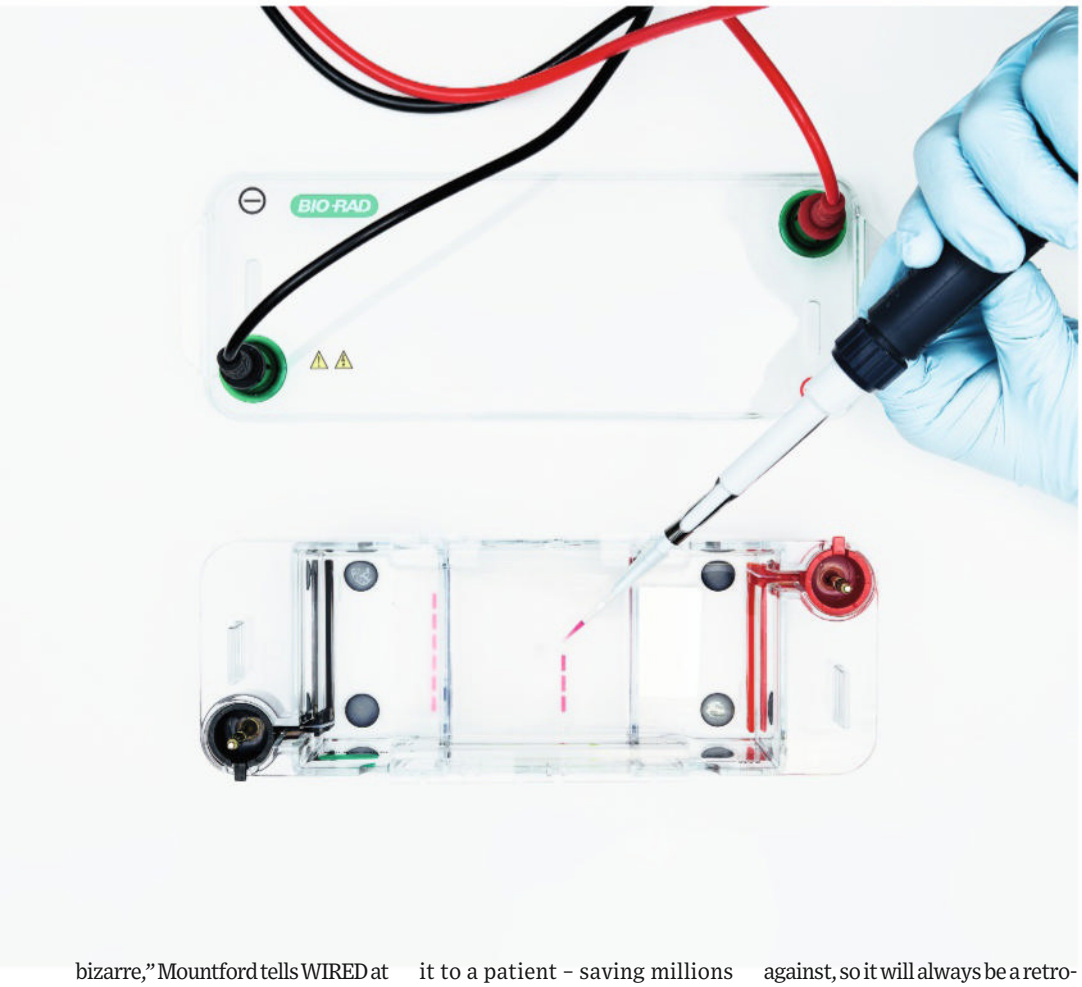
The British consortium, Novosang, wrote a 48-page report about how it would build such a machine, which it submitted to Darpa on February 14, 2008. As with all the other teams that applied, its application was rejected.

"They had some very specific requirements which were, quite frankly, quite impossible and

Joanne Mountford prepares a sample for flow cytometry in her lab at the University of Glasgow



‘WE STARTED TO REALISE THAT
THE IDEA OF MAKING BLOOD
IN A MACHINE – A SLOT MACHINE
FOR BLOOD – MADE SENSE’



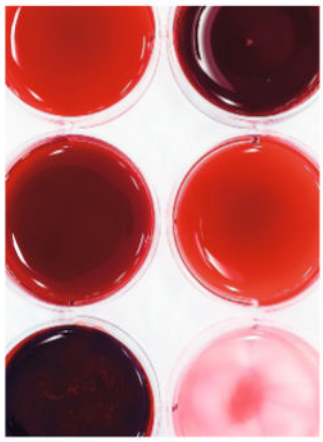
bizarre," Mountford tells WIRED at the University of Glasgow. She's in her forties, has thick, dark hair and smiles after her lengthy scientific explanations. Novosang always felt that it was never going to get Darpa's grant – the project was simply too pie in the sky. But what Mountford and the other British researchers came to realise was that manufacturing high quantities of blood from stem cells could actually be a solution to a very complex problem. Every year around the world, there are 100 million blood transfusions (around 2.2 million in the UK) – taking blood from a donor and giving it to a patient – saving millions of lives. But this simple therapy comes with significant potential complications. Although most blood services can filter donated blood against infectious diseases, there remains a risk of undetected pathogens slipping through. In the 90s, concerns were raised about undetected HIV. In 2013, British researchers estimated that one in 2,000 people in the UK carried the variant Creutzfeldt-Jakob disease. At the time there were three cases connected to transfusions – and there was no test for it.

"We don't know what that disease will be that we can't screen against, so it will always be a retrospective action to put it right," Mountford says. Furthermore, although national blood services in developed countries have sufficient reserves, in developing nations it's precarious. In the developing world, for instance, more than 150,000 women die every year from post-partum haemorrhage because there is no blood available for transfusion.

As a result, there is still a global need for clean blood. Mountford and her fellow Novosang scientists understood that an unlimited supplied of lab-grown, infection-free human blood could potentially save millions of lives. Soon after being rejected for the Darpa grant, they stripped out the most outlandish and unsubstantiated aspects of their report and submitted it elsewhere. Later that year, they received a grant from the Wellcome Trust and the Scottish Funding Council. To date, they have raised more than £12 million. The plan: to make a sustainable source of lab-grown blood.



'WE DON'T KNOW WHAT THAT DISEASE WILL BE THAT WE CAN'T SCREEN AGAINST, SO IT WILL ALWAYS BE A RETROSPECTIVE ACTION TO PUT IT RIGHT'



Above left: agarose gel electrophoresis, whereby an electric field separates DNA or RNA fragments to identify genes being expressed during cell differentiation

Above: non-lab-grown blood in various dilutions. The three lighter shades are similar to the concentrations lab-grown blood can reach

In the lab, human pluripotent stem cells (hPSC) are induced to differentiate into red blood cells. Here is Novosang's process mimicking what happens naturally in the body, inside the bone marrow.



The hPSC proliferate in a petri dish, with added proteins called differentiation factors.



The hPSC are cut into colonies that ball up into clusters of cells (embryoid bodies).

DONATED BLOOD NEEDS TO BE prepared before being sent to hospitals and clinics. A unit bag of blood, usually 430ml, is hung on a drip, where a filter removes all the white cells and clot-forming platelets. What remains is then centrifuged and the two remaining components – red blood cells and plasma – are separated. After the plasma is removed, the red blood cells are then labelled according to blood type and tested for infection. These cells are then stored in blood banks, ready for transfusion. The red blood cells are the only component of the blood used in transfusions.

Red blood cells are about eight micrometres wide and rich in haemoglobin, a protein that binds to oxygen and gives them their colour. We have approximately 25 trillion red cells in our bodies at any given moment. They have an oval bi-concave shape and lack a nucleus, which makes them highly flexible. This is a useful feature as red cells need to squeeze through blood capillaries as narrow as two micrometres wide to reach other tissues, where they deliver oxygen and remove CO_2 from our bodies.

Red cells circulate in the bloodstream for a period of around 120 days before they are digested by macrophages, a type of white blood cell, and cleared away by the liver. To replace them, new red blood cells are produced at a rate of two million every second from inside our bone marrow.

In the lab, Mountford wants to reproduce exactly what happens in the bone marrow when red blood cells are made. "We call them cultured red blood cells," Mountford says. "The key is that they are not synthetic and this is not an artificial process – they are the exact same red blood cells we produce in the body. It's just that they are grown in the laboratory. It's a product as nature intended."

Every cell in the body derives from a type of stem cell called pluripotent stem cell. Stem cells are, in a sense, the primordial cell from which every other cell is made as it matures through cellular differentiation. The maturation depends on the type of chemical and physical inputs in the surrounding environment. For instance, inside the bone marrow, where red blood cells are made, pluripotent stem cells first develop into a slightly more mature type of stem cell called a haematopoietic stem cell. This can give rise not only to red cells but to myriad other blood cells, such as T-lymphocytes and plasma cells.

"We can isolate these haematopoietic cells and grow them into red blood cells in the lab," Mountford says. "The difficulty is they're limited in their capacity to proliferate so we can only get a certain amount of red cells from any individual donation of bone marrow, so we would need to keep going back to donors. That's not a practical solution for the future."

In contrast, pluripotent stem cells can self-renew and proliferate indefinitely when grown in the lab. These cells are usually extracted from unused embryos from IVF treatments, with consent from the donors, and have the potential to differentiate indefinitely into any cells of the body. Of course, stem-cell research using embryonic cells has always been restricted due to ethical considerations regarding the use of embryos. However, those ethical issues were effectively circumvented in 2007



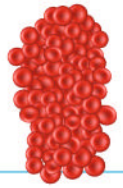
After ten days, the hPSC have been converted into blood progenitor cells.



They are directed to become red blood cells by the hormone erythropoietin.



Haemoglobin levels increase, the cells become redder, and the nucleus shrinks.



In the final step, the nucleus is ejected and the cell becomes a reticulocyte.

by Shinya Yamanaka, a Japanese biologist from the University of Kyoto, who was able to take mature skin cells – at a stage where they could no longer differentiate or divide – and, by adding four genes, turn them back into pluripotent stem cells.

In essence, Yamanaka rejuvenated the adult skin cells back to their primordial form so pluripotent cells could be turned into anything. "It seemed like alchemy at the time," Montford says. "It turned out to be the most incredible science I've seen in my career. He took cells which were terminally mature, fully differentiated, couldn't divide, couldn't turn into anything else, and he was able to revert them into a pluripotent nature so that they look and act identically to the human pluripotent stem cells from embryos."

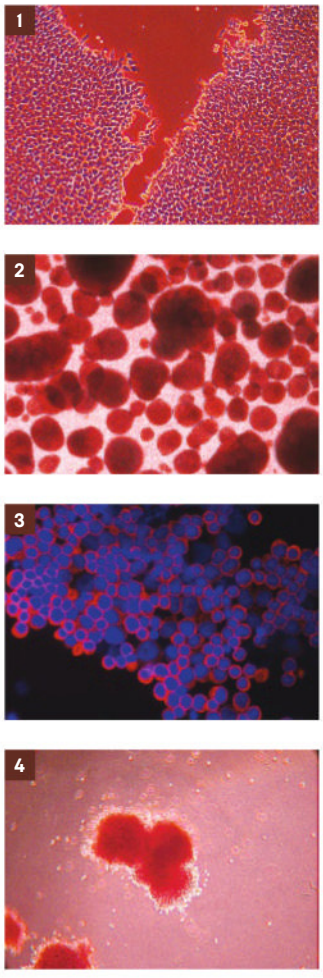
One year after Yamanaka's discovery, Robert Lanza, an American stem-cell researcher and one of the first scientists to clone an early-stage human embryo, made red blood cells from human embryonic stem cells. One Sunday afternoon in the summer of 2008, Mountford made a similar breakthrough. She received an image sent by one of her research students. The picture showed a 2.5cm Eppendorf tube, a plastic lab tube used in centrifuges. The picture was fuzzy, but clear enough to show red fluid on the bottom of the tube. "It was the first picture we have of red cells made from pluripotent cells," Mountford says. "It was nothing really, just 100,000 cells, around 8ml. And to get these 100,000 we had to put in about half a million cells, so from day zero to the end we were losing cells."

Today, Mountford and her team can produce 2×10^{12} red blood cells, the number of red blood cells in a unit of blood used in transfusions, out of nine million stem cells. "It's now sustainable and becoming a practical proposition, rather than having to have gazillions of cells at the beginning," she says.

YOUR BLOOD UNDER THE MICROSCOPE

The four key stages in blood manufacture, which Novosang is emulating in the lab

1. Pluripotent cell growing
2. Embryoid bodies
3. Cells with intact nuclei
4. Nuclei-free red blood cells



Opposite: red blood cells are grown at relatively low density; this centrifuge concentrates the samples for analysis



WHEN WIRED VISITS JOANNE

Mountford's lab at the University of Glasgow, she guides us through labyrinthine corridors until we arrive at the cell-culture lab. Inside a small room, there's a tissue-culture hood – an enclosed space designed to prevent contamination when handling cells. "Cells have to be handled in a sterile way," Mountford says. "Also, if they were hazardous in any way, the user would be protected as well." Next to the hood is an incubator, a humidified cabinet where stem cells grow inside tiny Petri dishes filled with a yellow liquid, a mixture of salts, sugars, amino acids and proteins. "These need feeding," Mountford notes. "We feed them every day. We give them all the good stuff that they can eat and specific growth factors to stop the cells differentiating randomly. Cells will differentiate on their own, given half a chance."

Mountford puts one of the dishes under the microscope, revealing a peninsular shape formed by thousands of cells on the plastic of the dish, separated by an empty area. Those, Mountford tells WIRED, are human embryonic stem cells in their early days. In a single dish there are about two million and, in theory, they can be turned into heart cells, liver cells, brain cells and, of course, blood cells. On top of this layer are bigger cells that seem to float. "Those cells are starting to differentiate spontaneously," Mountford says. "That's what we have to fight against. We have to stop them doing their own thing and get them to do what we want, which is [become blood] cells."

Mountford produces another dish. "This is about day ten of the differentiation process," she says. "They're deciding if they want to be haematopoietic or not." There are star-shaped cells stuck to the bottom of the dish and little balls of cells coming from them. "The stellate ones are vein cells, and haematopoietic cells are generated from them. They can turn into any kind of blood cell. We haven't yet nudged them into being a red cell."

Obtaining red blood cells from pluripotent induced stem cells remains a very complex problem. The pluripotent stem cells have a genetic programme that's still very open and permissive, whereas a mature differentiated cell, such as a skin cell or a hair cell, has most of its DNA closed down. "The sequence has not changed, but the way it's packaged is altered," Mountford explains. "In a mature cell, all of the options the cell doesn't need are switched off. This expression was driven by the proteins and growth factors that were added in. A pluripotent stem cell, on the other hand, doesn't have anything switched off yet. All the options are still open."

Turning a pluripotent stem cell into a red blood cell takes about 31 days. Throughout that period the researchers need to follow a "recipe" with the right ingredients given to the stem cells at the right time and in the right doses. Finding the recipe is a haphazard task. "We just put things in, change the timings and see what happens," Mountford says. "What we would ideally like to do is to be able to put them in a dish and then systematically work out what's needed in what dose at what time. That's the way things are starting to move. It's basically suck-it-and-see for a lot of it."



UC DOUAY, A RESEARCHER at the Pierre and Marie Curie University in Paris, became in 2012 the first – and so far only – researcher to conduct a human clinical trial with red blood cells derived from stem cells. "He took adult stem cells, turned them into red cells and put them back into the same individual as proof of principle that this can work," Mountford says. "He found that red blood cells made from stem cells lasted longer in circulation than donated red cells."

Today, Novosang includes researchers from the universities of Cambridge, Glasgow, Edinburgh, Bristol and Loughborough. It's planning to run the first in-human trial in 2017, using red blood cells produced from adult stem cells. The objective will be to assess how manufactured red cells survive in comparison to donated cells. Ten volunteers will receive a transfusion of donated red cells and, six months later, a transfusion of manufactured red cells. "We've got all the expertise that's required across different blood services to lead in this field," says Nick Watkins, assistant director of research and development at NHS Blood and Transplant. The study will take about 18 months to run.

One of the side effects of regular transfusions is accumulation of iron in the liver and the heart. This is a problem that can be mitigated by lab-grown red blood cells. "The blood cells derived from stem cells survive longer than donated cells," Watkins says. "If you're a patient who requires regular transfusions, one of the biggest complications is iron overload. But if you increase the time between transfusions you can maybe reduce complications."

Mountford agrees: "In a normal bag of blood, every single red blood cell is a different age. One might be a day old, another 120 days old – the average lifespan of a red cell. The distribution of ages in a bag is random. But red cells grown in a lab will all be young and freshly produced, so the transfused blood will last longer in a patient."

The challenge for Novosang is to manufacture red blood cells in sufficiently high quantities and in an economically sustainable way. A bag of blood produced using stem cells currently costs around £30,000 to make. In comparison, an average unit of blood at the NHS costs around £140 for about 450ml. "That's without the infrastructure costs," Mountford says. "When you cost in the blood services it's significantly higher; I'm not sure that we have an absolute number."

The other problem is to make enough. "When we get to clinical trials, we're going to have to go up to 1,000-litre bioreactors," Mountford says. "If we're ever going to produce the full UK annual requirement – 10^{18} cells – we're looking at very large plants. We always hope that Grangemouth [Scotland] will stop petrol production. That would be good for us. It's close." W

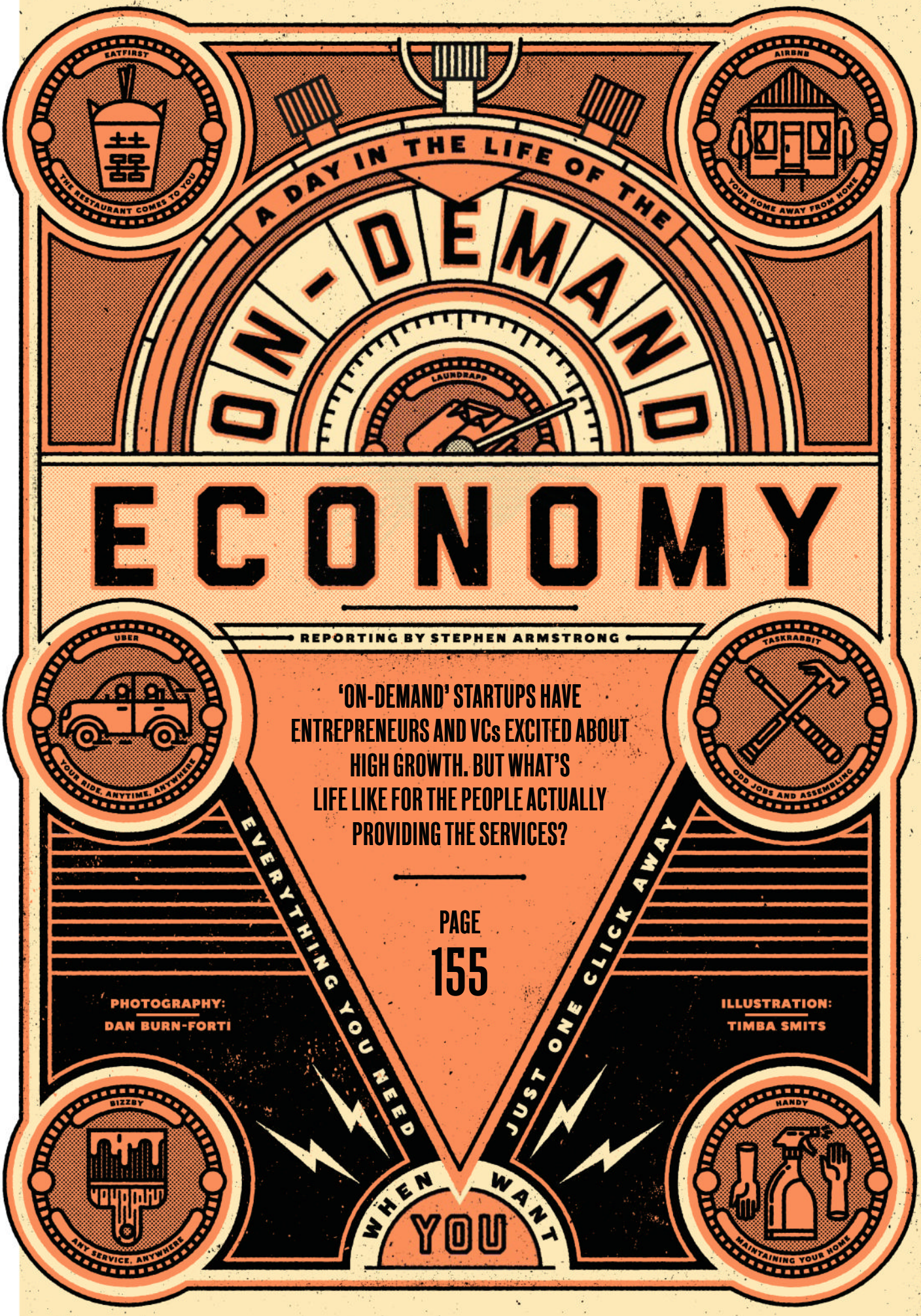
João Medeiros is WIRED*'s science editor. He curates the R&D section*

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EVERYTHING YOU NEED
JUST ONE CLICK AWAY
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ILLUSTRATION:
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BIZZBY
ANY SERVICE, ANYWHERE
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MAINTAINING YOUR HOME
WHEN WANT YOU



1 EATFIRST

NAME: RAMON MAYOR | **AGE:** 26 | **STATUS:** PART-TIME | **OTHER JOBS:** DRIVING

RATE: £4 PER HOUR + £5 PER DELIVERY | **REGULAR TASKS:** "DELIVERING PRE-COOKED CHILLED MEALS."

"The craziest time is signing in at 6pm – if you're running late, you never quite make that up," Ramon Mayor, delivery driver for EatFirst, explains. He came to the UK from Spain in March 2014. He was driving for a Spanish family, but lost his job as the economy shrank. "There's no shortage of driving jobs in the UK," he says. "All the drivers have several driving jobs."

The firm pays £4 per hour, with a £5 bonus for each delivery in central London – drivers typically make two or three per shift. With cash tips, Mayor earns, on average, £40-45 per day for an eight-hour shift. The company, backed by Berlin's Rocket Internet incubator, launched with a 15-minute order time, offering two meal options, but has since expanded its menu and range while reducing the service to evenings only. Mayor welcomes recent plans to re-introduce lunchtime deliveries: "For me, driving was just the start. I'm moving into an operations role, organising drivers for the company. I'm ambitious."

2 TASKRABBIT

NAME: MIKE JONES | **AGE:** 26 | **STATUS:** PART-TIME | **OTHER JOBS:** ACTOR | **RATE:** £25 PER HOUR

REGULAR TASKS: "ASSEMBLING FLAT-PACK FURNITURE. SOME PEOPLE DON'T REALISE THAT IT COMES IN A BOX."

TaskRabbit – which launched in 2008 – is an odd-job marketplace, offering anything from standing in a queue at the Post Office to admin. Customers choose a service, enter their postcode and see a list of taskers, who set their own rate (usually between £12ph and £25ph depending on experience, ratings and reviews), with a minimum booking of one hour.

Mike Jones signed up 18 months ago, after graduating from drama school. "I don't really want to get hired to paint someone's house, in case an audition comes up – so in that respect, TaskRabbit can be unpredictable in terms of where you're going," he says. "But it's still a pretty regular and stable income compared to acting." Jones charges the top rate of £25 per hour – but he's classed as an "elite" tasker with a 100 per cent positive feedback rating on over 100 tasks. TaskRabbit takes 30 per cent of his fee for his first task with a new client, dropping to 15 for repeat bookings.



3 AIRBNB

NAME: CAROL FEDIDA | **AGE:** 56 | **STATUS:** PART-TIME HOST | **OTHER JOBS:** NONE

RATE: £99 PER NIGHT/ROOM; £299 PER NIGHT/APARTMENT | **REGULAR TASKS:** "PREPARING THE FLAT, LIAISING WITH GUESTS."

Carol Fedida's 280m² Clerkenwell penthouse has been on Airbnb for two months – she was previously on rival site onefinestay. "I thought there wasn't enough communication between the hosts and the guests at onefinestay," she says. "They handle everything and aim for a hotel-style experience, which is fine for some, but I felt like I had no control." Fedida prefers to talk to her guests directly. "I prefer letting the spare room more than the whole place – it's like having people to stay."

The average UK Airbnb owner earns £5,600 per year from their property, according to figures provided by the company, with Airbnb taking a three per cent host service fee, and a guest service fee of between six and 12 per cent. October was relatively successful for Fedida, who took £2,400. "You do get some guests asking for a discount or trying to cut a deal direct," she explains. "But I'd rather stay within the system, because I know I'm going to get paid and I'm covered if they cause damage."



THE AVERAGE AIRBNB OWNER IN THE UK EARNS £5,600 PER YEAR

4 BIZZBY

NAME: NICK RAVENSCROFT

AGE: 36 | **STATUS:** PART-TIME

REGULAR TASKS: "CHANGING HALOGEN BULBS IS BIG."

OTHER JOBS: MUSICIAN

RATE: £89 PER HOUR

BIZZBY launched in January 2015, offering on-demand services and charging a flat rate per hour depending on the task – £12ph for cleaning, £45 for gardening, £89 for electrical/plumbing etc. There's a minimum charge of one hour, and BIZZBY takes 20 per cent. Ravenscroft has provided electrician services through the firm for six months. He previously worked furnishing flats and houses for high-net-worth individuals, but says the freedom and money are better working through BIZZBY.

"Last week I got £700, but that included a few late nights," he says. "The last really late one was screwing the legs on to a TV in Mayfair. That was £60 an hour. It depends what you're prepared to do."

The worst job, he explains, is fixing macerators – the motorised waste grinders attached to domestic toilets.


BIZZBY
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5 UBER

NAME: NEHA RANI

AGE: 31 **STATUS:** PART-TIME

REGULAR TASKS: "DRIVING PEOPLE TO MEETINGS."

OTHER JOBS: MOTHER

RATE: AVERAGE £20 PER HOUR

Rani came to the UK from Pakistan aged 14, and worked as a beautician until her first daughter arrived in 2004. After her husband left, she became a minicab driver. She joined Uber 18 months ago and works around ten hours per day, divided to accommodate school hours and childcare.

She typically earns £20 per hour – a vast improvement, she says, on her minicab earnings, which peaked at £80 for a shift, but could be as low as £26. Work-related expenses amount to around £110 per week on petrol, vehicle maintenance and insurance.

Every week, Uber tots up each driver's acceptance rate, which should ideally stay above 80 per cent. Rani's rating is usually 98: "I pick up everyone – even badly rated customers," she says. "They're usually just people who were drunk once. They're so grateful someone took their fare."

'THE CORPORATE WORLD WAS GREAT, BUT I DECIDED TO GO THROUGH A TRANSITION'



6 HANDY

NAME: OZZY MONACO **AGE:** 50 **STATUS:** FULL-TIME **OTHER JOBS:** NONE

RATE: £8-9 PER HOUR **REGULAR TASKS:** "HOME CLEANING."

"I think it's to do with learning about Buddhism, but I don't like walking into a person's home with shoes on," Handy cleaner Ozzy Monaco says. "I slip on flip-flops. I don't call it cleaning houses, I maintain them. I work on the feng shui." He has been working as a cleaner for Handy for a month. He spent most of his career in France – including a spell in academia and consulting for the likes of LVMH. "The corporate world was great, but I decided to go through a transition," he says.

Handy launched in the UK in 2014 and, last September, acquired cleaning app *Mopp*. The company charges £10 per hour for cleaning, with a minimum two-hour booking, and takes between ten and 20 per cent, depending on volume of work and customer rating. Monaco is saving to buy land in Slovenia. He takes his first job at 7am, works to 9am, switches back on at 3pm and works till 5pm. "I earn £8-9 an hour. For an acre in Slovenia – if I stay with Handy for eight months, we'll be there."

7 LAUNDRAPP

NAME: GERGO KAPOSI | **AGE:** 28 | **STATUS:** FULL-TIME | **OTHER JOBS:** NONE

PAY: £8.50 PER HOUR | **REGULAR TASKS:** "MAINLY SHIRTS AND SUITS."

Kaposi left a restaurant job in Hungary and worked as a casual driver before signing up to laundry and dry-cleaning app *Laundrapp* in May 2015, just after its £4 million funding round. Customers book pick-up and drop-off times, and the app tracks drivers, sending a text with a ten-minute window for arrival. "Making sure you hit that ten minute window can be tough," Kaposi explains. "Most negative customer ratings are down to missing it." Kaposi dons a company regulation blue shirt when his shifts start at 6am or 2pm. Mornings are stay-at-home parents; lunchtimes are often dirty gym kit from office workers; evenings are male and female singletons. Orders range from an entire football team's kit to a single teddy bear.

Kaposi earns roughly £8.50 per hour – a lower rate than some rival laundry services, although he points out that, unlike its competitors, Laundrapp does have its own fleet of vans rather than expecting drivers to provide their own.



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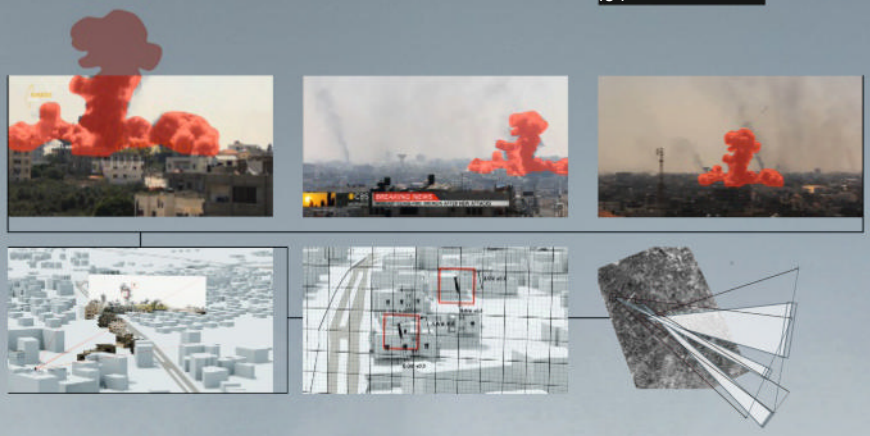
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Images provided by Forensic Architecture (*top row*) show a bombing on Friday, August 1, 2014, in Gaza. The position of the videographer can be determined by comparing a frame of video to a 3D simulation of the city (*second row*). The size of the bombs can then be ascertained. The intersection of three videos shows the strike location (*pictured far right*)

HISTORY, RECONSTRUCTED

BY
MICHAEL HODGES

PHOTOGRAPHY:
SAM BARKER

All stills and footage are input into a database called the Image Complex, a set of manually drawn relationships. From there, they can be ordered into a chronological sequence



IN THE HEAT OF WAR, 'TRUTH' CAN BE FUZZY. SO A LONDON TEAM ARE BRINGING FORENSIC TOOLS TO UNRAVEL CLASHES FROM GAZA TO GUATEMALA

‘SMOKE CLOUDS ARE METADATA: THEY HOLD INFORMATION REGARDING BOTH SPACE AND TIME.’

The voice is melodious and calm; the scene playing out on the laptop is not – intense cobalt-yellow flashes from detonating ordnance precede pillars of black smoke that partially mask the city beneath.

The images and sound come from an online report by Forensic Architecture (FA), a south London-based research organisation whose approach to data collection and analysis is changing the way human rights controversies are investigated, in part by using mobile-phone footage from ordinary people. “The concept of testimony is being completely reformatted,” the organisation’s director Eyal Weizman tells WIRED. “Usually, human rights organisations have to wait days, even months, and collect things from memory. But these are testimonies of people who were there, technological testimonies through their cameras and videos.”

Compiled in partnership with Amnesty International, the media-rich document is called *Black Friday – Carnage in Rafah During 2014 Israel/Gaza Conflict*. The strikes are from US-made Mk84 bombs that were dropped by the Israeli Air Force on the al-Tanur district of Rafah in southern Gaza on Friday, August 1, one of the most intense 24 hours in 2014’s seven-week war between the Israel Defense Forces (IDF) and the Palestinian group Hamas. Each bomb contained almost 500kg of high explosives.

The FA report is playing on a laptop in the conference suite of the Ambassador Hotel in Arab East Jerusalem’s diplomatic quarter. It is August 1, 2015, a year to the day since the air strike, and Weizman is about to publicly launch *Black Friday* and also the online platform that FA has designed to carry the report, an interactive tool which the group will be making available as open-source software in the hope it will be used by observers of other conflicts around the world.

There is a frisson among the assembled Israeli, Palestinian and international journalists when Weizman – a compact and bearded man, today wearing chinos with trainers – enters the room, trailing a wake of officials from Amnesty International and members of his team. Weizman is an academic star: the 45-year-old Israeli is professor of spatial and visual cultures at Goldsmiths, University of London – home to FA’s headquarters – and is also an associate professor at Princeton. As the director of Forensic Architecture, Weizman has invented a new academic discipline, perhaps even a whole new science. “But this is not cold science,” he says. “This is committed, engaged, citizen science.”

FA investigators take standard architectural and digital tools such as telemetry, video-footage syncing and shadow clocks, and repurpose them to reveal the secrets of conflict zones. Weizman’s team has also pioneered plume analysis – the study of the whirling clouds of mainly atomised concrete created when bombs are dropped in urban areas. Each plume has a distinct shape, like a fingerprint. Weizman and his colleagues’ brief is as wide-ranging as man’s cruelty to man: they mine the information seam where enemies clash, where migrants drown, natives are dispossessed and civilians bombed.

One of its most notable projects, the “left-to-die boat” case, used FA’s mapping skills, survivor reports, mobile-phone records and nautical charts to show how western powers – present in the area in great naval force – consistently ignored the pleas of a stricken boat carrying 72 migrants from Libya to Italy, leaving it adrift for two weeks in March 2011.

When possible, the team furnishes prosecutors with evidence to be used in court cases and international tribunals, so that human rights violators can be brought to justice. It has mapped the Guatemalan military’s genocidal campaign against indigenous peoples in the 80s, producing an interactive online report. Its work on US drone strikes in the Waziristan province of northern Pakistan exposed the price paid by civilians for the west’s continuing war against Islamic militants in the region and pioneered the use of 3D landscapes as a reconstructive memory chamber for civilian survivors of military attacks. FA’s staff are activists as much as investigators and, although they often use existing techniques, they approach them with a fierce, almost political will.

This will comes directly from Weizman. He has written many award-winning books such as *Hollow Land: Israel’s Architecture of Occupation* and *The Conflict Shoreline*, with photographer Fazal Sheikh. Weizman’s work uses post-modernist cultural theories about politico-physical structures and legal processes to explore the mechanics of conflict, especially the near-century-old conflict in Palestine.

Right: Eyal Weizman photographed in Forensic Architecture’s headquarters in south-east London

The Israeli-Palestinian conflict aside, it is a strange and unsettling dispute – where the air above your head is contested and the ground beneath your feet subject to claim and counterclaim. It's a conflict in which the architecture of the region is itself a weapon as much as the Palestinian Qassam rockets or the Israeli Merkava tanks.

The most obvious example of this is the security wall next to the West Bank. Weizman has written about it at length. Israel-Palestine is criss-crossed with other borders and divisions; some are the baffling results of the 1993 and 1995 Oslo Accords which, in the hope of peace, divided the occupied territories into Areas A, B and C. Others, such as the Green Line, mark the end of fighting that took place as long ago as 1948.

Weizman is a product of this contested landscape. "I have lived half my life in the UK," he says. "But my formative years were here. I feel a great love for this place and I know it very well. To operate, politics needs obstruction, it needs the know-how, the love, the familiarity with every stick and stone in the area. Putting your body where your politics is, is very important."

One case particularly influenced Weizman's thinking – the death in 2009 of Palestinian demonstrator Bassem Abu Rahma in the West Bank village of Bil'in. While demonstrating against the wall that encroaches on the village's land, the 31-year-old was fatally wounded by a tear-gas canister fired over the wall by Israeli forces. To investigate, Weizman utilised what he calls "citizen-video analysis". Human rights activists – often from the Israeli group B'Tselem – regularly film demonstrations such as those at Bil'in. Three video cameras caught the moment when Abu Rahma, wearing a yellow football strip, was hit in the chest by what FA claims, and claims to have proved, was a deliberately aimed round.

According to the FA report into the death of Abu Rahma, the video footage contains "much spatial information". After syncing the three films of the event by using clues on the soundtracks, the team created a digital model of the area around the wall where the incident took place. They were then able to position all the participants, including Abu Rahma and the Israeli soldiers who shot him. This made it possible to study each moment in the unfolding of the event and even to trace the path of the tear-gas canister's trajectory – which led to a soldier and a weapon. The report concluded: "the weapon was being aimed... with the likely purpose of killing or maiming the demonstrator."

The FA's accompanying digital evidence was covered by media and, in a rare event, the Israeli military prosecuted one of its men. However, to Weizman's dismay, the case was dropped in September 2013 because of "lack of evidence".

Incidents such as the Bil'in campaign pit Weizman against the Israeli government, which is wary of him. Getting into the country can



be testing: his trips are often rushed and each time he doesn't know how difficult security will make things for him. Some of the Israeli reporters in the Ambassador Hotel room ask: what about Hamas? Where is the report about them? Amnesty International has issued a report called *Strangling Necks*, detailing Hamas's torture, abduction and summary execution of fellow Palestinians during the 2014 war. Nonetheless, some Jewish groups in the region regard Amnesty as biased against Israel. Weizman's team faced death threats before the launch, including the following message: "I plan on visiting you with an M-16 very soon. Consider yourselves warned." Accordingly, three plain-clothes Palestinian security men are concealed among the crowd.

Weizman knows about the death threats, but he is calm when he takes the podium. The wider circumstances



'I PLAN ON VISITING YOU WITH AN M-16 VERY SOON. CONSIDER YOURSELVES WARNED'

of August 1 are generally agreed; it is the specifics that Weizman wants to reveal. The morning had begun optimistically: the UN- and US-brokered 72-hour ceasefire had come into effect and hundreds of civilians were returning to homes they'd fled. They came on foot, by car, by donkey and cart. As they streamed back eastwards along the main Salah al-Din Street route, codenamed Tancher by the IDF, an Israeli air and ground assault was unleashed on al-Tanur.

Both sides contest who broke the ceasefire. The IDF was searching for the tunnels Hamas uses for offensive operations and investigating a Hamas outpost in fields near the border with Israel. In the engagement that followed, one Hamas fighter and two Israeli soldiers were killed. A wounded Israeli, second lieutenant Hadar Goldin, was seized and taken into the tunnel complex.

The IDF responded by implementing the Hannibal Directive. This simply means doing everything possible to prevent a soldier being taken captive – even if that means the soldier's death. An Israeli military inquiry found that more than 2,000 bombs, missiles and shells were fired into Rafah on August 1, including 1,000 in the three hours following the capture. The response would continue for four days. Amnesty estimates civilian deaths in Rafah at between 135 and 200. Goldin was killed as well, although by which side remains uncertain.

Even as the assault was being unleashed, it was being documented and analysed. Across Rafah, Palestinians, human rights volunteers and medical workers were reaching for their smartphones; on rooftops, news organisations were training their cameras on the bomb bursts; and 694 kilometres above, the French Pleiades satellite was passing over Gaza.

It meant investigators were able to collate a vast amount of data. According to Amnesty, the FA team had access to "testimonies from victims and witnesses; reports by human rights and other organisations; news and media feeds, public statements and other information from Israeli and Palestinian official sources; and videos and photographs". By using shadow clocks and hi-res images of tank tracks left over the four days of fighting around al-Tanur, they were also able to let the land itself tell the story of the bombardment.

THE DIGITAL ANALYST

Christina Varvia
Forensic Architecture researcher

"I analyse the available sources, extracting material and then making sure that this analysis can be visualised in a way that communicates well.

"With each image we try to find the location and time so that we can build a system and understand exactly where and when a bomb fell. We do this through a series of techniques. We locate a piece of footage – for example, the video of the al-Tanur strike – and we try to figure out where the photographer was sitting. We are basically identifying certain sites we can find on the footage. Then we mathematically analyse the perspective to understand exactly the view frame of the camera - what is it framing? We do this because in every other process we need an exact location not just a rough idea of where it is. We need to know the exact orientation of the footage. It's a process of measuring the buildings' distance from the photographer, treating it as an elevation, testing it as a drawing and then transferring that.

"My colleague Gustav is producing animations and graphic material for our reports on the Gaza and Rafah projects. He is working on a way of using the photos to construct 3D models from them. Something like this exists already, as photogrammetry. This is a different kind of process that we're using with software and animation. It uses existing architectural software but we are re-appropriating the tools in a way that's closer to animation – creating 3D objects and placing them in footage. We are pushing the tool to its limits."

Four ways in which Forensic Architecture, with SITU Research, is shedding light on conflict

MEDITERRANEAN SEA

Left-to-die boat

The Forensic Oceanography project, led by Charles Heller and Lorenzo Pezzani, focused on the deaths of 63 migrants in March 2011 in the Mediterranean – the "left-to-die boat" case. The boat was being monitored by the Nato-led coalition intervening in Libya. The team could reconstruct how events unfolded and demonstrate how different actors used the complex jurisdictions at sea to evade their responsibility for rescuing people in distress.

GUATEMALA

Ixil Maya people

The team studied the violence inflicted by Guatemalan state security forces on the Ixil Maya people in the El Quiché region of West Guatemala from 1978 to 1984. The study attempts to read the environment not just as the location of conflict but as the means by which it unfolds. This research formed a report produced on behalf of the prosecution in the case of genocide committed against the Ixil people.

PAKISTAN

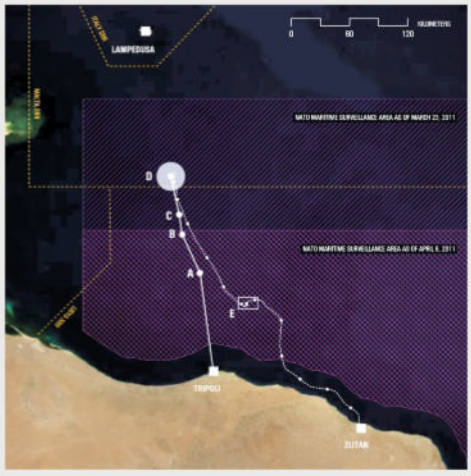
American drone strike

A US drone missile was dropped on a dwelling in Miranshah in North Waziristan on March 30, 2012. It was designed to penetrate a ceiling and then detonate, spraying steel fragments. This case analysed video testimony smuggled out of the area in order to reconstruct the space of the strike and to interrogate the event. Where the shrapnel distribution is absent, it's likely to be because it was absorbed by something, perhaps a human being.

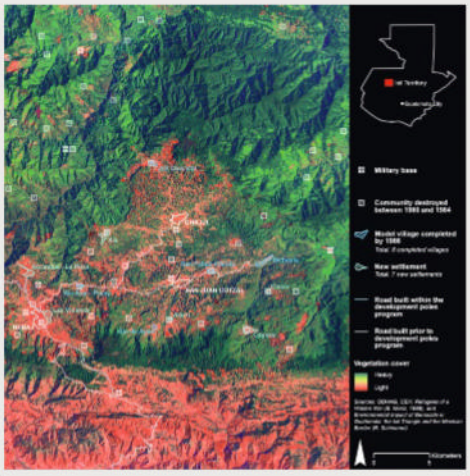
WEST BANK

Nil'in

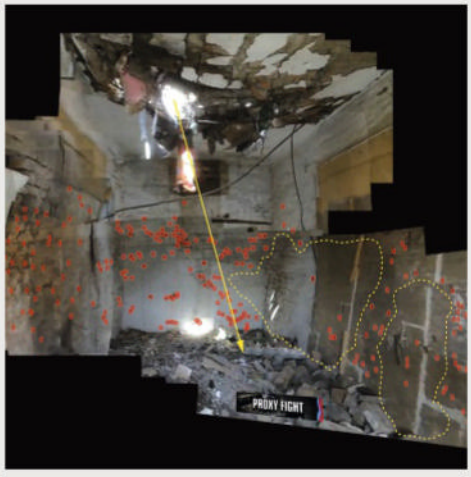
On July 7, 2008, Ashraf Abu Rahma was detained while engaging in a non-armed demonstration against the separation wall next to the village of Ni'lin. Seventeen-year-old Salam Kanaan filmed the incident from her house nearby. Her video shows an Israeli commander holding Abu Rahma's arm while a soldier shoots him in the foot. The soldier claimed he could not see Abu Rahma. The team undertook a spatial reconstruction of the footage to ascertain what happened.



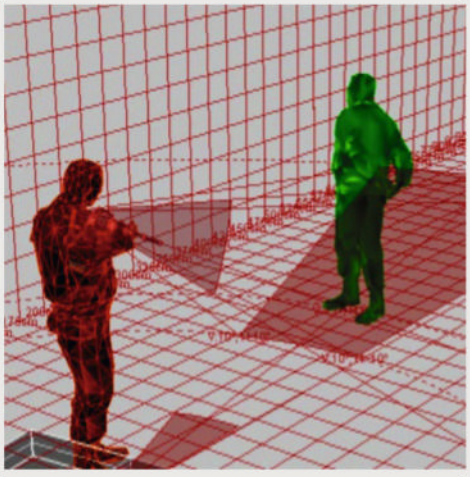
MEDITERRANEAN SEA



GUATEMALA



PAKISTAN



WEST BANK

"For us, the question is how the city senses war," Weizmans explains to WIRED in his small office at Goldsmiths in Deptford. "A war starts; tens of thousands of foreign people enter into a familiar city that has hundreds of thousands of people in it and at that moment everything starts recording. People's memory records, the grass records, the trees record, the plumes in the air record, the concrete records. Everything is recording in a variable way. But these sensors are weak, fucked-up sensors. You need to develop ways of interpreting and reading and mediating those things."

By analysing smoke plumes, FA investigators say they could determine exactly where the IDF dropped Mk84s. By studying bomb craters and the tracks of bulldozers and signs of digging, they concluded that in order to end Goldin's imprisonment the IDF set out to destroy both the tunnel networks and any possible escape route via Tancher.

'PEOPLE'S MEMORY RECORDS, THE TREES RECORD, PLUMES IN AIR RECORD, CONCRETE RECORDS'

As well as Palestinian witnesses, the *Black Friday* report includes the testimony of Israeli soldiers collected by the veterans' organisation Breaking the Silence. "After the area was hit by 1,000 shells that Friday morning, I saw Tancher in ruins," one shocked soldier said of the destruction of the area. "Everything was totally wrecked."

The previous cycle of violence in Gaza in 2008-2009 also had many civilian casualties. But in that conflict the deaths of 900 Palestinians and three Israelis were less publicised at the time than those in 2014. Weizman points to one key difference: "Social media," he says. "In 2008-9 all the expertise, all the testimonies, were after the fact. In the five years since then a flood of images has opened up, there is much more stuff from the



At 11.39am on August 1, 2014, a European satellite called Pleiades happened to be passing over Gaza and took a single, high resolution photograph. This image is a rare insight into the day of conflict as it developed. It is possible to see a recent explosion, areas burning and tanks moving into position. The resolution of 50cm per pixel was previously unavailable for satellite images of Gaza because of the US monopoly and a US-Israeli agreement that forced all satellite images of the area to be masked by a low-resolution veil – European satellites do not have such restrictions. PHOTOGRAPHY: CNES 2014, DIST. AIRBUS DS, ALL RIGHTS RESERVED





THE PLATFORM SPECIALIST

Francesco Sebregondi
Forensic Architecture researcher, project architect, PATTRN

Based at Goldsmiths, University of London, Francesco Sebregondi is a researcher and project architect of PATTRN, a new open-source app for data visualisation and mapping.

"The tool facilitates the mapping of complex events based on different data sources – it's a form of data-driven, participatory fact mapping. Increasingly in the cases we work on with Forensic Architecture, we are dealing with vast amounts of data fragments – reports of events, photographs, videos, social-media posts and satellite imagery. We realised that we needed a platform to compile all this data, cross-reference it and start to understand the relation and hidden connections between dispersed events.

"So we developed PATTRN, which works as an online visualisation platform that enables the user to explore all the data compiled in a database. People can directly submit data to the platform, so that the big picture of an ongoing event can be built collaboratively.

"With the global spread of smartphones and social media, conflicts and protests around the world are increasingly reported by the very people that experience them first-hand. Syria, Ukraine or the Ferguson riots, are all cases in point. But it's also difficult to make sense of this mass of data, and to distinguish between the facts and rumours. PATTRN sets out to address these new conditions, and to support more transparent and citizen-driven information about these complex events."

In August 2015, Weizman drives WIRED through East Jerusalem to the Old City. We pass the 15-metre-high Ottoman walls, which are still imposing, despite the highway that runs beneath them. Weizman gleefully explains the Arkansas Big Mac – US President Bill Clinton's surreal, in retrospect, plan to portion out the space occupied by the remains of the biblical Jewish temple and Islam's Haram al-Sharif by horizontally dividing up the air, the Earth's surface and the territory beneath it. An internal border would have run under the floor of the Haram al-Sharif, buffered by a 1.5m-thick UN zone and then Israeli territory.

The windscreens of tourist coaches on the Mount of Olives glint as Weizman continues down into the Kidron Valley, through contested scrub the Israelis claim was King David's city, and enter the Arab township of Silwan. The community is under constant pressure from settler groups who believe it is the right and duty of Jewish people to live here and Israeli archaeologists have been digging beneath Silwan's margins in search of signs of an ancient Hebrew capital. Here in the tumbledown vertiginous closeness of Silwan's housing blocks, Weizman explains how to read a landscape like a forensic architect. He notes where the road has been cracked by the subsidence caused by the excavation as he halts on the much-repaired Tarmac. "The dips in the road, the bumps, every crack – they are all witnesses," he says.

"The idea is always to use forensic architecture as a method that extends deep into the historical facts and looks at them and maps them out to see the materialisation of political forces. Forensic Architecture assumes that every bit of material reality is the product of a complex force field that extends in space and time. So you can take an inanimate object and see into it, almost like a crystal ball."

No crystal ball is required in the landscape south of Jerusalem; the signs of architectural conflict are all around us. The built landscape is an Escher drawing: Israeli-only roads go through tunnels driven under occupied mountains; the Jewish settlement of Gilo looks across the valley to Palestinian Beit Jala, the highway between them supported on Israeli concrete pillars that stand on occupied ground.

Entering the eight-lane checkpoint that marks the beginning of the West Bank proper, Weizman explains the complicated dog-legs and U-turns he must perform to successfully get round the checkpoint system and drive

ground. And also a change in satellite images. Previously we had access to US satellite images and an act of Congress meant all US images taken over Israel were pixellated. But in 2014, there was a French satellite above Gaza, and they're not regulated by that. So for the first time the war was captured in high-resolution images."

During WIRED's first meeting with Weizman and his Goldsmiths team they were looking at those images. One of the analysts, 26-year-old Greek architecture graduate Christina Varvia, was cross-checking the video footage against satellite images on her desktop. "We were very lucky that this particular strike that you are seeing here has actually been recorded by the satellite," she says. "The satellite has very accurate metadata – this picture was at 11.39am."

One still from al-Tanur showed two bombs in mid-air. "The material is quite harsh," Varvia says, "but part of the reason we do this is because we understand the heaviness of it."

Weizman acknowledges the contributions of the witnesses. "Sometimes they risk their lives to take those images," he says. "You hear the distress of people; they say things as they record and see people dying around them. These are valuable real-time testimonies that not only reflect what happened but the state of mind of people right at the moment it happened. Our way of valuing that is to listen to all their bytes and pixels, to find whatever is hidden in them."

east into Beit Sahour, a Palestinian village outside the West Bank city of Bethlehem. He was a founding member of the architectural collective DAAR here and still keeps an office.

But today he is turning right off the highway and heading west into fully Palestinian-controlled territory. An ominous red signpost warns: "This road leads to area a under the Palestinian Authority. The entrance for Israeli citizens is forbidden, dangerous to your life and is against Israeli law."

Weizman shrugs at this instruction from his mother country. He has been discounting strictures since he was a teen embarking on the military service which all of Israel's Jewish citizens – with the exception of the ultra-religious – must complete. "I refused to serve in the West Bank," he says. "I kept putting down my gun, grabbing my bag and walking home." Each time he was caught he was brought up with other absentees before an officer with a reputation for severity and each time he contrived to avoid imprisonment – using a ruse WIRED has pledged not to reveal – until, eventually, the IDF gave up chasing him and he went home.

'I REFUSED TO SERVE IN THE WEST BANK. I KEPT PUTTING MY GUN DOWN, GRABBING MY BAG AND WALKING'

Such relentlessness would bring Weizman a remarkable victory at Battir, a Palestinian village he describes as "a small jewel, and a tiny garden". Battir sits right on the 1967 Green Line that most international organisations envisage as the eventual border if there is ever to be a two-state solution. Driving through Battir's outskirts we pass the Christmas cake-white mansions of rich Palestinians – one of which is due to be demolished because its footprint strays out of Area B, joint Palestinian control, into Area C, Israeli control, a case Weizman has worked on but fears he has lost. Twitchy guards patrol inside the high iron fence, awaiting the arrival of IDF bulldozers.

Beyond that the road slopes down to reveal the main village perched above a hillside divided into 3,000-year-old agricultural terraces. The Roman cistern that feeds the terrace irrigation system of open channels and sluices is the oldest in the Holy Land. This agricultural and archaeological resource came under threat when the Israeli army decided it was going to run the separation wall along the border here. The security road that runs alongside would have destroyed the lowest terraces.

Smarting from the events at Bil'in, Weizman decided to change tack. "It had been an error entering into a debate with the Israeli military in an Israeli court arguing for human rights," he says. "But Battir was not a claim about rights; it was a claim on behalf of the landscape. Of archaeology, of nature."

To illustrate what he means he walks along the Green Line, the 1967 border marked here by the old Jaffa-Jerusalem railway. Weizman picks his way through terraces planted with vegetables and fruit trees. Across the valley on the Israeli side there is no sign of habitation and the hills are covered in conifers. "That is how you know that side is 1948 Israel and this side Palestine," says Weizman. "The tree planting."

Weizman shows how the lower terraces would have disappeared if the wall had been driven through here. FA used digital modelling to illustrate the effect of the proposed route of the wall through Battir. "We submitted the file for UNESCO listing, as well as evidence there with testimonies from Palestinian farmers and even Israeli settlers who didn't want to see the terraces demolished." UNESCO gave Battir the listing, putting pressure on the Israeli high court to stop the wall. In January this year it was finally decreed that no wall would be built at Battir.

Here, at the scene of that judgement, Weizman's previously scholarly manner finally slips. "It was a landmark case," he says as we look down on the terrace. "There will be no wall here. There will be a permanent gap in the wall. It is a small victory and the danger is successes like this make the process more acceptable and allow the bulldozers to go in elsewhere but, yes, it felt good."

Not content to be the man who stopped the wall, Weizman wishes to use the precedent he established at Battir to stop all wall building – to move, in his view, towards a just settlement of the conflict. "It was that terrace that won the case," he says. "We learned that human rights take you nowhere in this area, but if you claim on behalf of mountains you have a case. Battir was saved because of its natural beauty, historical significance and religious significance," he says. "I would claim that is the case with the whole of Palestine."

It wasn't just 21st-century technology that won the day. Villagers could give Weizman an oral history of the land they lived on, tell him exactly what grew in each terrace and how long it had grown there. In building his digital picture of the landscape Weizman was able to plug into Battir's collective knowledge, a folk memory that goes back to a time before modern borders or states. Each farmer knows the history of each fruit tree, the planting cycle of each terrace.

"We understand the relationship between memory, architecture and violence," Weizman says. "Take the woman who survived the drone strike in Waziristan. She was very traumatised; she lost relatives in there. We returned her digitally to the site of the attack and built it together with her, reconstructed her family house that had been hit by the drone. During the modelling process she was meticulous about every window, every object we placed in there, every person. But she was very obsessed with a fan. In the beginning she said it was on the ceiling. Then she said no, it was a standing fan. She asked us to move it to the left and then to the right and then back again, until we were wondering, what is it about the fan? But when we made her walk through the space she recollected exactly where it had been, and that after the strike had killed her family she had found bits of human flesh on the blades of the fan. You see, the fan acted as an anchor for her memory and in the end we managed to reassemble that memory in a digital space."

Later in the day Weizman drives out towards the towers of Tel Aviv. Presently the traffic brings him to a halt as if he were in a city like London or New York, where everyone has sophisticated technology in their pockets and, thanks to social media, the chance to record and share what they see. Weizman has found a way to harness these, our everyday digital diversions, for a fierce, moral purpose. "With forensic architecture you work at the micro but your eyes are on the macro," he says. "Whether it's the terraces at Battir, the cracks in the roads of Silwan or the bombs in Rafah – whatever it is, you fight over the last rock." W

Michael Hodges wrote about North Korean dissidents in 04.15

SOLAR, **ECLIPSED**



Photography: **BRYAN DERBALLA**



COAL? OR THE SUN?

THE POWER SOURCE INDIA CHOOSES MAY DECIDE THE FATE OF THE PLANET

BY **CHARLES C MANN**

A NUMBER OF FUNCTIONARIES WITH documents in envelopes wait outside the small office of EVR Raju, the environmental manager of the Jharia coalfield in north-east India. It's the the country's biggest, covering some 440km², and most significant; this status comes not only from the amount of coal it produces, but the fact that it has been on fire, calamitously, since 1916; entire villages have collapsed into the smoking ground. Raju has the job of putting out the fire so that his company can double the mine's output in the next five years. Whether – and how – he can perform this task will have a significant impact not just on India, but the entire world.

He waves aside a minion who offers tea. "The prime minister said the fires have to go out," he says. "He said money was no issue. He made a statement a few days back. Things have to happen fast."

India has the world's fastest-growing major economy, is its biggest weapons importer, is on track to become the most populous nation (probably by 2022), to have the biggest economy (possibly by 2048) and potentially the largest military force (perhaps by 2040). Nowhere is India's influence more significant than on climate change. For years, attention has focused on the role of China, the largest emitter of greenhouse gases, and the US, one of the largest per capita emitters. In November 2014, the two nations promised substantial limits on greenhouse-gas emissions for the first time; China has pledged that its CO_2 output would fall after 2030, and the US has vowed to cut its output by more than a quarter in about the same time. Indeed, China's emissions have fallen so fast in the past year that many believe it may achieve its target ahead of time.

India's carbon output, by contrast, is growing faster than any other country's. Should that trend continue, India could surpass China in 25 years to become the world's greatest emitter. Its increasing emissions could offset all the efforts at curtailment in the rest of the world. "India is the biggest piece of the puzzle," says John Coequyt, Sierra Club's director of federal and international climate campaigns. "Is there a way for that rapid growth to happen quickly and pull people out of poverty using a lot more renewable energy than has ever been used before? Or will they build more of what they have – huge coal plants with almost no pollution controls?"

The inevitable conflict between India and other nations could come to a head as early as December's international climate talks in Paris. India appears to be participating only reluctantly – it was the last major nation to release an emissions plan. Although the plan projected big increases in solar and wind power, energy efficiency and reforestation, it didn't actually promise to cap greenhouse gases. It also demanded rich nations pay for most of the cost, which it estimated to be "at least $2.5 trillion [£1.6tn]... between now and 2030" – more than $166 billion a year for the next 15 years. Within weeks, environmental groups complained that India was threatening to capsize the negotiations, holding the whole world hostage to its demands.

Matters look different inside India. There, officials and academics have long argued that western nations are demanding that India industrialise without burning even a fraction of the fossil fuels that developed nations consumed when they industrialised. And Indians resent that western nations insist on the right to judge Indian performance while refusing to help with the cost of transition. "The west – not India – filled up the air with carbon dioxide," says Sunita Narain, director general of the Centre for Science and Environment in New Delhi. "The west is asking us to pay for its mistakes. They are saying, 'Oh, you are a rich country now, you can cover the cost.'"

A "premature superpower", in the words of economics writer Martin Wolf, India is focused on both increasing its influence abroad and raising its living standards at home. Its per capita income is just $1,778. (The comparable figure for the UK is $45,603; China's is $6,050.) Even India's wealthy are poorer than their counterparts in the west; of the nation's richest ten per cent, a third live in households with no fridges. Worse, 300 million Indians – a quarter of the population – have no electricity. Nearly as many have only intermittent access to it. Most of these people cook their food on wood or dung fires. The smoke kills about 1.3 million Indians a year.

Providing power to these literally powerless people is "a priority in every imaginable way – human, economic and political", says Navroz Dubash, a senior fellow at the Centre for Policy Research in New Delhi. Partly in consequence, India's demand for electricity is widely expected to double by 2030. The government



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The Jharia coalfield has been on fire for a century.
Opposite: dust-coated solar panels must be routinely washed.
Previous page: scavengers picking for coal at one of the mines near Lilori Patra, in the Jharia coalfield

of Prime Minister Narendra Modi is determined to satisfy that demand. In fact, Modi – arguably the most powerful Indian prime minister in three decades – is pursuing this goal by charging down not one, but two paths, each fraught with difficulties.

The course touted most by outsiders is an aggressive programme to expand solar power. In his former position as chief minister of the western state of Gujarat, Modi oversaw the construction of Asia's biggest solar park, a giant utility with battalions of solar panels. Soon after being elected prime minister in 2014, he announced that India would produce 100 gigawatts of solar power by 2022 (the US now has about 20 gigawatts). Earlier this year, India unveiled plans to build the world's biggest solar park, in the northern state of Madhya Pradesh. This path is next to impossible: no nation has ever expanded its renewable-energy infrastructure at the speed Modi envisions. India could easily spend huge sums and still fall short, leaving tens of millions of people in the dark.

Simultaneously, Modi is forging a second, contradictory path: to power the nation using India's vast coal reserves, among the top five in the world. Increasing output will require transforming the corrupt, hidebound state enterprise Coal India and moving a million people out of the way to extract the coal. To generate electricity from it, India plans to build 455 coal-fired power plants, more than any other nation – indeed, more than the US now has. (India's existing 148 plants, which provide two thirds of its electricity, are among the world's dirtiest and most inefficient.) This strategy has a brutal downside: vastly increased carbon emissions that would make it nearly impossible to prevent global temperatures from rising more than 2°C, the goal of the Paris talks. Higher temperatures will have catastrophic implications around the globe – and India, with its long coastline, scarce water supplies and hot climate, may be more vulnerable to the effects of climate change than any other big nation.

Last summer, WIRED spent three weeks in India, speaking to academics, activists, businesspeople and politicians concerned with the nation's energy and climate issues. Not one person believed India had the financial muscle to pursue both paths. One will have to be downsized, or even abandoned. In practical terms, the nation will end up making a choice: more coal or more renewables. That choice will affect the lives of the hundreds of millions of Indians who today live without lights, fridges, air conditioners, telephones or the other necessities of modern life. But its ramifications will also ripple across the rest of the world.

"Indians used to be furious at the way decisions in the west – decisions in Washington and London they had no say in – could upend their lives," Narain says. "Now, I sometimes think, people in the west will understand what that feels like."

FROM AN AEROPLANE WINDOW, THE coastal state of Gujarat seems like a monument to the ambitions of its native son, Narendra Modi. In former badlands 160 kilometres from Ahmedabad, its biggest city, one can see sunlight reflecting from the Charanka solar park, Asia's biggest. Dozens of rectangular photovoltaic arrays were scattered in a broad U over a kilometre on each side. Thirty-five kilometres from the airport was a metallic ribbon, nearly a kilometre long and over 30 metres wide: a solar park built atop an irrigation canal. South-east of the city was a second, a 3.5km tunnel of aluminium and polymer. As the plane approached the Tarmac, solar panels stood like sentinels atop buildings everywhere – a vision of a green future, almost all of it brought into being by the preternaturally determined Modi.

Modi was born in 1950, the son of an impoverished tea-stall owner in a remote Gujarat town. Charismatic and with a resonant origin story, he has a passion for politics and a reputation for flexible ethics. From adolescence, he worked as an operative for the Rashtriya Swayamsevak Sangh (RSS – National Volunteer Organisation), a nativist outfit dedicated to the idea that India is an essentially Hindu nation, founded on Hindu beliefs and ideals. It has a network of schools, charities and clubs run by disciplined cadres of conservatively dressed activists – and a violent aura; it has repeatedly been accused of organising attacks on Christians, Muslims, Sikhs and other non-Hindus.

In 1987, Modi joined the Bharatiya Janata (Indian People's) Party (BJP), a pro-Hindu, nationalist party tied to the RSS. He rose steadily and won election as chief minister in October 2001. A few months after the vote, a Gujarat train loaded with Hindu pilgrims and activists caught fire, killing dozens of passengers. Angered by rumors that the blaze



IN 2010, INDIA ANNOUNCED SEVEN SOLAR-ENERGY-STORAGE PROJECTS. ONLY ONE HAS BEEN BUILT

was started by Muslims, club-wielding Hindu thugs murdered a thousand or more people, most Muslim. Human-rights groups charged that the BJP had encouraged the attacks. Modi, they said, stood by as Muslims died. An inquiry dismissed the accusation, but the riots stained his reputation; in 2005, he became the only person ever denied a US visa for "severe violations of religious freedom". (The decision was reversed in 2014.)

Alarmed by the fallout, Modi shifted gears, refashioning himself as a sharply dressed, tech-friendly progressive who lured major companies, foreign and Indian, to invest in Gujarat. He also became one of the world's most prominent advocates for solar power. In a "green autobiography" published in 2011, Modi promised to transform hot, dry Gujarat, with its 55 million people, into a model of sustainable development, increasing irrigation and recharging aquifers, converting thousands of cars and trucks from petrol to natural gas and turning the state capital, Gandhinagar, into a "solar city". He created Asia's first ministry of climate change and led a pioneering programme to install solar panels atop irrigation canals, shielding the canals from evaporation and generating power without covering scarce farmland.

Getting to that tomorrow will be difficult. During WIRED's visit to Charanka, it was about 43°C and windy. Dust, whipped into the air, obscured the Sun and coated the solar panels. Pipes beneath the arrays carried water to wash them. Solar parks, farms for electrons, effectively had to be irrigated. Here and there, the serried lines of panels wobbled, nudged out of alignment by harsh conditions and land subsidence. Energy from the Sun today is responsible for about one per cent of India's electricity; even in Gujarat, it amounts to just five per cent. Optimistic government scenarios show it rising to ten per cent by 2022. The state-owned Power Grid Corporation of India has proposed creating huge installations in Indian deserts to increase solar's share to 35 per cent by 2050. Little that WIRED saw in Charanka made these goals seem plausible. Not one person we contacted at the park would speak on the record; Gujarat Power, the state-run developer of the project, had stopped issuing triumphant press releases. (Gujarat has quietly junked its climate-action plan.) Perhaps the lack of interest in accommodating foreign journalists meant nothing. But the silence when WIRED asked about the other part of solar power – energy storage – seemed to speak volumes.

For solar panels to provide electricity at night, power generated in daylight must be stored. Typically storage systems employ the Sun to heat a liquid (water, say, or molten salt); at night the stored hot liquid drives a steam turbine, producing electricity. In 2010, India announced seven solar-energy-storage projects, one in Gujarat. Only one, in another state, has been built. The others were abandoned when the builders discovered that the air is so hazy their initial estimates of potential solar power were out by as much as a quarter.

Renewable-energy advocates state that these difficulties can be solved with sufficient will and money. That's why so many of them cheered Modi's election as prime minister in May 2014. The BJP promised in its election manifesto to "put sustainability at the centre of our thoughts and actions."

A month after his election, Modi pledged he would deliver electricity to all Indians by 2019. Soon after, he moved the date to 2022. But to accomplish that, Modi about-faced, increasingly emphasising coal. That September he conspicuously skipped a UN climate summit. The same month, the man whose autobiography denounced the "carefully orchestrated campaigns" to foment scepticism on "whether or not [climate change] was happening" told an audience of children "climate has not changed. We have changed... God has built the system in such a way that it can balance on its own." In November that year, he said India would double coal production by 2019, when, he said, a billion tonnes a year would be produced.

FIVE HUNDRED AND FIFTY METRES below the surface, the ancient coal-mine elevator opens into a space lined with icons of Kali Ma, goddess of the hungry earth, the deity most important to miners. Railway tracks march into the distance, disappearing in the haze. WIRED is standing in the Moonidih mine, one of 23 in the Jharia coalfield in north-east India. The air is hot and intensely humid despite heroic efforts at ventilation. Forty minutes' walk away is the mine face, black and glittery in workers' headlamps. A giant bore with a 1.8-metre drill crunches into the wall with shocking ease. Streams of water play on the head to prevent the coal dust from igniting. Wet black shrapnel flies everywhere. Behind the machine is a series of conveyor belts, rumbling one after another, conducting a black stream of coal rubble to a bunker almost seven kilometres away.

The massive coalfield is owned by Bharat Coking Coal Ltd (BCCL), a subsidiary of Coal India, one of the country's biggest companies. Coal India owns more coal reserves than any other corporate entity in the country. Still, Jharia and BCCL occupy a special place in India's future. In addition to being Coal India's biggest colliery, Jharia is the nation's most important domestic source of prime coking coal, the hard coal that is an integral part of steel production – it both provides the necessary heat and the carbon that makes steel strong. Because any imaginable path towards matching the west's development involves making massive amounts of steel, ramping up production at Jharia is a top national priority. Achieving Modi's billion-tonne target, company officials tell WIRED, will require the colliery to increase its output by about 15 per cent a year.

The men and women who must accomplish this huge task work in a landscaped headquarters that, during our visits, is full of people standing around in hallways and lobbies without obvious purpose. One morning, WIRED interviews an able young engineer. Jammed into the other half of his office are half-a-dozen older men, one of them his supervisor, drinking tea and telling stories. The interview lasts nearly two hours. During that time the other men do not move. Phones do not ring. Email alerts do not ping. Keyboards lie untouched. The office door opens only to admit flunkies with tea on a tray. Perhaps the activists who protest against India's ambitious coal expansion plans would be comforted by this scene. Increasing productivity is going to be no easy task.

The difficulties are not all internal. The Jharia coalfield has been on fire for a century, consuming and ruining huge amounts of coal, and continuing



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A scavenger carrying coal in the Jharia coalfield. The area produces prime coking coal used in steel production



to imperil dozens of villages. When WIRED visits the area one evening, toxic fumes, issuing from the cracks in the Earth, wreathe the buildings and the black, leafless trees. Patches of smouldering red are scattered like watching eyes across the charred landscape: it's like Mordor without the Orcs.

When the coalfield opened in the late 1800s, people who wanted work simply moved into the area around the mine. In legal terms, they were squatters, but nobody wanted to drive away the workforce. In time, the city of Dhanbad – population about 2.7 million – grew atop the eastern end of the deposit. Dhanbad is no squatters' camp; it is a bustling, relatively prosperous city, complete with grocery shops, restaurants, middle-class apartment blocks and bird-stained statues of dead Indian notables. To increase production from Jharia, BCCL will not only have to put out the fire, buy millions of dollars' worth of new drill-and-conveyor assemblies and stabilise the land riddled by fire, it will also have to relocate a large fraction of this city, its satellite communities and the burned villages in the next few years.

Because India is a democracy, people can resist such government plans. The de facto leader of the local anticoal movement is a middle-class businessman called Ashok Agarwal. A member of the Dhanbad chamber of commerce, Agarwal lives in a pleasant two-storey structure built by his grandfather. His machine-parts business is on the ground floor; his struggle against BCCL, which has lasted 20 years of protests and litigation, is headquartered in his home, amid patterned rugs, cheerful paintings and photographs of family members. Indian law requires that BCCL relocate not only the villagers already displaced by fire but all the people who will be affected by the mine's expansion, he says. "That's 700,000 families," he says. "More than two million people." Has the Indian government ever constructed an entirely new city of that size overnight? "I don't think any government has," he says. "When they talk about doubling coal output, they don't mention this part." The part about moving an entire city? "Yes – that part."

Similar efforts must occur in many other places in India to fulfil Modi's goal. Unfortunately, about 90 per cent of Indian coal is not Jharia-style coking coal but low-quality, highly polluting thermal coal. Outdoor air pollution, most of it due to coal, is already responsible for 645,000 premature deaths a year, according to a study published in *Nature*. New Delhi, ringed by coal plants, is said to have the world's most polluted air. Burning more coal will only make the situation worse. Already India has a high rate of chronic respiratory disease. "Success would be a disaster," Agarwal says to me. "I don't see how they get to a billion tonnes."



DEVELOPMENT IN INDIA WILL INVOLVE MASSIVE AMOUNTS OF STEEL. THAT MEANS MASSIVE AMOUNTS OF COAL

EVEN THE SMALLEST INDIAN villages have a shop or two – and Luckman, in the southern Indian state of Karnataka, is no exception. At the edge of town stands a single kiosk, no bigger than an old-fashioned news stand. Basic supplies fill its unpainted shelves: rice, lentils, oil, chickpeas, beedis (hand-rolled cigarettes made by wrapping leaves around tobacco flakes). At night, it has Luckman's only electric light: a six-Watt LED lamp, powered by what looks like an old car battery. From the battery dangles a cable that leads to the kiosk roof, on which sits a battered solar panel about the size of a cafeteria tray. This is what solar power looks like in much of rural India.

When WIRED walks over at about 8pm, the owner is asleep with his head on the counter. Still, the store is open – the illumination allows him to keep the kiosk going after dark. Behind the clerk, a small girl crouches on the floor, doing homework in the pool of light. And behind her is an old woman, methodically rolling beedis for sale. The extended hours, the ability to do homework after chores, the chance to earn extra income – all of it comes from a single light.

Enabling even this small amount of electricity has long been a struggle. India's villages can be astonishingly remote by western standards; a hamlet may be only 80 kilometres from a city but be next to impossible to reach, especially when the rainy season makes roads impassable. Stringing and maintaining transmission wires in such circumstances is a nightmare.

In network jargon, India has a last-mile problem, referring to the way that bottlenecks are often found in the link that physically reaches the customer's premises. Because of this challenge, the cost of building India's electrical grid was so high that rural farmers often couldn't afford to pay for their connection. To solve the problem – and to shore up sagging popularity among poor voters – the government launched a programme in the late 80s to provide free power to low-income tribal families. Unfortunately, over time and at great expense to utilities, the benefits of the programme were mostly captured by wealthier, more politically powerful families. Today, 87 per cent of Indian household electricity is subsidised, but less than a fifth of the subsidies go to the rural poor for whom they were intended, and the utilities have little incentive to spend what it would take to connect them. Even if India floods the sky with coal smoke, the 300 million Indians without power still might not get connected – the worst of all possible worlds.

Enter Harish Hande. Born in 1967 and raised in the eastern state of Orissa, he won a scholarship and obtained an engineering PhD at the University of Massachusetts Lowell. His dissertation focused on rural electrification. When Hande returned to India, he went to the southern city of Bangalore, where he bought a solar home-lighting system with the last $300 from his scholarship. He sold it, installing the system himself. The transaction earned Hande enough to purchase a second system, which he sold,

and then a third. He found a US partner who helped him obtain additional funding. In 1995, the two men incorporated a for-profit business, the Solar Electric Light Company – Selco. As Hande slowly built up his customer base, he kept asking villagers why they didn't already have electricity. For decades they had been waiting futilely for government agencies to fulfil promises to provide power. Why couldn't they go out and just get it themselves by installing solar panels?

According to Selco's technical manager Jonathan Bassett, the single biggest problem was financial: classically risk-averse loan officers at local banks found ways to avoid lending money for solar projects. Hande and his team came to believe that the route to India's energy future ran through the offices of low-level bank functionaries. Persuading and cajoling, experimenting and testing, they gradually installed 300,000 solar-power systems in remote villages in southern India and Gujarat, along with 45 branch offices to provide service and maintenance. As a rule of thumb, Bassett tells WIRED, "We won't install systems without a branch that's less than two hours away."

Increasingly, Selco is expanding beyond individual installations – the kiosk in Luckman is one – to village-wide projects. The key, Bassett says, is the "local guy who runs the kiosk". Selco installs solar panels adjacent to the store. The electricity feeds a charging station inside the kiosk. Clipped into the station are small batteries, each the size of a cigar. At dusk, participating families send someone to fetch their battery. It connects to a Selco six-watt LED via a standard VGA port (the unusual plug both helps deter theft and makes it harder to damage the devices by amateur fiddling). In the morning, the families return their battery for charging. They pay 25 rupees a month (about 25p) for the service. The next step, now being tested, is village solar networks – with greater capacity and independent "minigrids" that allow participants to run fans, sewing machines and computers.

Selco is far from alone; dozens of other solar ventures exist in the Indian countryside, though few have been as successful. Because solar energy is intermittent, many Indians see it as second class; a Greenpeace minigrid experiment in the north-eastern state of Bihar last year was met by villagers chanting, "We want real electricity, not fake electricity!" But Selco-style projects have a signal advantage: they can expand rapidly. Selco's installations are increasing at a 20 per cent annual clip. More importantly, the company is training 100 entrepreneurs a year to replicate its business model across the country. Instead of building huge solar parks or giant coal plants and trying to distribute electricity to remote villages, it is attempting to make the villages themselves the source of power. Hande envisions a bottom-up movement, with entrepreneurs training entrepreneurs. With luck and favourable government policies, it could represent a third path to the future – one quite different from anything as yet envisioned by Modi.

Whatever decisions India makes on the road to providing power for its hundreds of millions of unwired people, its choices will resonate around the world. Its popular prime minister has alternated between promoting renewable energy, as he did in Gujarat, and increasing the focus on coal. Neither is an easy path. Grid-style solar power requires building both massive new Charanka-style solar plants and massive energy-storage facilities, all on a scale that has never been seen in the world. It is a daunting prospect. Coal is cheaper, and there is little mystery about how to use it. But obtaining enough for India to prosper will require Coal India and other companies to sort through enormous logistical and humanitarian difficulties. And even if Modi managed to surmount them, he would be burdening India with a huge pollution problem – and the rest of the world with CO_2 emissions. The nation cannot follow both paths equally. Modi, in his shifting allegiance, seems to be signalling a preference for coal.

Still, one can envision another course, in which bottom-up efforts like those from Selco could buy some time, giving rural Indians some of the most important benefits of electrification while allowing the nation to build up its renewable infrastructure. No serious study has yet laid out the conditions under which this could occur. But it is hard to believe this could happen without significant financial assistance from developed nations. (There is also the moral argument: as Narain said, the west did fill the atmosphere with carbon dioxide first.) But ultimately the decision about assistance will be made by Europe and the US. India will make a choice, but it will not be India's alone. ■

Charles C Mann is the author of 1491 *and* 1493 *(Granta)*



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A temple in the village of Nilkanta Rayan Gaddi, which gets electricity from a Selco minigrid system powered by solar energy. **Opposite:** coal moves down a conveyor belt at the Moonidih mine in Jharia

BLOOD SHED TO CREATE THIS ISSUE
WIRED will do anything to bring you award-winning design: take deputy creative director Ben Fraser, who bravely spilled at least a finger's worth of claret while channelling Jackson Pollack for our blood feature.



OVERHEARD AT WIRED THIS MONTH
"Apple News launched today – you can get it if you update your iPhone to the new OS. And there are loads of new emoticons, FYI!"
"I'm conditioned to compost. I can't actually imagine life without it."
"I think we might be overstretching ourselves" – editor's realisation, four years too late.
"Sorry, I missed what you said. I was thinking about the Millennium Falcon…"
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IMPERIAL STAR DESTROYERS THIS MONTH
Model maker Ben Millar constructed the Star Destroyer *Abrams* for our cover feature: "My inner geek leapt at the chance to build such an iconic spaceship. It's mainly MDF, with a skin made from laser-cut acrylic that has panelling etched into the surface – along with J.J.'s face. Most of the fine details are in the hangar bay – we used scavenged parts from a WW2 flak gun model kit."








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Swiss jewelled watch movements from the 1920s - 1950s. Backed with vintage leather and mounted as cufflinks.
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Nanoleaf



Let your voice be the light switch. The Nanoleaf Smarter Kit offers revolutionary wireless lighting control with Apple HomeKit-enabled voice commands. Just say "turn on my lights" and presto, it's done. Dim down, turn them up or set the perfect mood instantly.

For more information visit **www.nanoleaf.me**

OTONE Audio



BluWall Direct from OTONE Audio allows for Ultra High Definition Audio...Anywhere. BluWall Direct is a portable multi-room speaker which creates it's own dedicated network, allowing you to connect up to 8 speakers together without the need for a home network. BluWall Direct is also able to play high-fidelity, Ultra High Definition audio. You can do all of this, anywhere thanks to an 8 hour battery life.

Available now for £179.99 from **www.otoneaudio.com** or Selfridges in the Trafford Centre, Manchester or Oxford Street.

Urban Jürgensen

The current Urban Jürgensen Collection reflects the brand's devotion to Honouring Timeless Traditions in handcrafted elegant timepieces. Their aura of restrained excellence means their watches are appreciated by Collectors and Connoisseurs worldwide. The stunning new collection includes 5 new watches. Seamlessly blending an application of pure hand craft and style, they display all visual landmarks of distinction that can only be found in Urban Jürgensen timepieces, and are perfect for anyone who seeks the very finest things in life!

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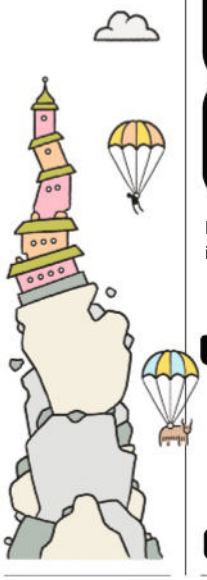
THE WIRED INDEX

12 dollars

The amount for which a former Google employee, Sanmay Ved, was able to buy the domain Google.com on September 29, 2015, due to an administrative error. The transfer lasted for just a minute before Google reversed it. Ved received a reward from the company

2,039

The number of wheels of Parmigiano-Reggiano cheese, worth €785,000, that were snatched by a gang in Modena, Italy, between November 2013 and January 2015. Police arrested a total of 11 suspects in September 2015



8,881

People killed in the April and May 2015 earthquakes in Nepal. Some reached up to 7.8 on the Richter scale

15

Number of people who died in the September 2015 earthquake in Chile, whose magnitude was 8.3. The South American country had created an earthquake task force and passed strict anti-seismic regulations following a disastrous quake in 2010



102

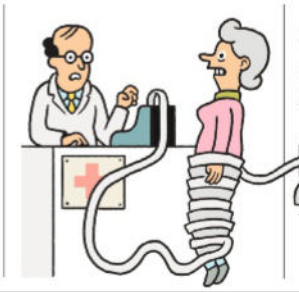
The distance, in kilometres, that scientists at the National Institute of Standards and Technology in Maryland teleported quantum information using optical fibre. It was quadruple the previous record. Quantum teleportation is regarded as key for developing quicker, quantum-based computers

17,000

Phone calls that the Automobile Association receives every month from customers who cannot understand the meaning of a warning light on their car's dashboard

22

The number of bloopers in the 2015 movie *Jurassic World*, according to MovieMistakes.com



5,555%

The price increase of anti-parasitic drug Daraprim, whose cost per pill rose from $13.50 to $750 after its manufacturer was acquired by Turing Pharmaceuticals

3.2

The percentage in 2014 of Chinese women who were smokers, according to *The Lancet* medical journal

156

The number of mistakes in the original 1993 movie, *Jurassic Park*, according to the same site

$73.5 million

Tax revenue from recreational marijuana that the state of Colorado collected in the first seven months of 2015

68

The percentage of Chinese males who smoke. The same study adds that one third of all cigarettes are smoked by Chinese men

WORDS: GIAN VOLPICELLI. ILLUSTRATION: GIACOMO GAMBINERI. SOURCES: LINKEDIN; QUESTURE; ONEMI; OSAPUBLISHING; THE AA; MOVIEMISTAKES; GOODRX; THE LANCET; COLORADO.GOV



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